AD-753 070

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Teledyne Geotech

Prepared for:

Advanced Research Projects Agency

7 November 1972

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TECHNICAL REPORT NO. 72-[illegible]

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

FINAL REPORT, PROJECT VT/[illegible]

CONTRACT F33657-72-C-[illegible]

1 July 1971 through 30 June 1972

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TELEDYNE
GEOTECH

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Teledyne Geotech 3401 Shiloh Road Garland, Texas 75041	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Operation of Tonto Forest Seismological Observatory Final Report, Project VT/2704, Contract F33657-72-C-0013, 1 July 1971 through 30 June 1972

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

5. AUTHOR(S) (First name, middle initial, last name)

Geotech Staff

6. REPORT DATE 7 November 1972	7a. TOTAL NO. OF PAGES 65	7b. NO. OF REFS

8a. CONTRACT OR GRANT NO. F33657-72-C-0013 b. PROJECT NO. VELA T/2704 c. ARPA Order No. 1714 d. ARPA Program Code No. 1F10	9a. ORIGINATOR'S REPORT NUMBER(S) TR 72-8 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for Public Release; Distribution Unlimited.

11. SUPPLEMENTARY NOTES Details of illustrations in this document may be better studied on microfiche.	12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency Nuclear Monitoring Research Office Arlington, Virginia 22209

13. ABSTRACT

This is a report of the work accomplished on Project VT/2704 from 1 July 1971 through 30 June 1972. It describes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona, research and test functions carried out at the TFSO, and research and development tasks performed by the Garland, Texas, staff using TFSO data.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Long-Period Array Short-Period Array Seismograph Operating Parameters Multichannel Filter						

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TECHNICAL REPORT NO. 72-8

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Final Report, Project VT/2704
Contract F33657-72-C-0013
1 July 1971 through 30 June 1972

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Advanced Research Projects Agency
Nuclear Monitoring Research Office
ARPA Order No. 1714

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TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas

7 November 1972

I-C

IDENTIFICATION

AFTAC Project No:	VELA T/2704
Project Title:	Operation of TFSO
ARPA Order No:	1714
ARPA Program Code No:	1F10
Name of Contractor:	Teledyne Industries, Inc., Geotech Division Garland, Texas
Contract No:	F33657-72-C-0013
Effective Date of Contract:	1 July 1971
Amount of Contract:	$206,855
Contract Expiration Date:	30 June 1972
Program Manager:	B. B. Leichliter 271-2561, ext. 222

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1. INTRODUCTION

1.1 AUTHORITY

The research described in this report was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, and was monitored by the Air Force Technical Applications Center (AFTAC) under Contract F33657-72-C-0013, dated 1 July 1972. The Statement of Work for Project VT/2704 is included as appendix 1 to this report.

1.2 HISTORY

The Tonto Forest Seismological Observatory (TFSO), located near Payson, Arizona, as shown in figure 1, was constructed by the United States Corps of Engineers in 1963. TFSO was designed to record seismic events and to be used as a laboratory for testing, comparing, and evaluating advanced seismograph equipment and recording techniques. The instrumentation was assembled, installed, and operated until 30 April 1965 by United Electrodynamics (UED) - later Earth Sciences, A Teledyne Company - under Contract AF 33(657)-7747. In March 1964, the Long-Range Seismic Measurements (LRSM) Program provided eight mobile seismic recording vans to extend the existing instrument arrays at TFSO. On 1 May 1965, Geotech assumed the responsibility of operating TFSO. The LRSM vans were phased out of the TFSO operation on 3 October 1965. During the 20-month period from 1 May 1965 through 31 December 1966, the operation of TFSO under Project VT/5055 was closely allied with the work performed at the Blue Mountains, Uinta Basin, and Wichita Mountains Seismological Observatories under Projects VT/1124, VT/4054, and VT/5054. When reasonable, operating procedural changes, observatory instrumentation improvements, and special research investigations were accomplished simultaneously at all observatories. In other instances, improvements, modifications, and/or procedures that had been developed and proven at another observatory were incorporated into the TFSO operation. During 1967, under Contract AF 33(657)-67-C-0091, Project VT/7702, a 37-element, short-period array and a 7-element long-period array were designed and installed.

Figure 1. Location of the Tonto Forest Seismological Observatory

1.3 WORK OF PROJECT VT/2704

The work of Project VT/2704 was a continuation of the work of earlier TFSO projects. The work of this project can be divided into the following general categories:

a. Continued operation of TFSO;

b. Evaluation and improvement of the standard instrumentation to provide a more efficient and effective observatory;

c. Field testing of newly developed and experimental instrumentation;

d. Analysis of resulting seismometric data;

e. Incorporation of new equipment into the systems operating at the TFSO.

2. SUMMARY

Three seismograph systems - the 37-element short-period array; the 7-element, 3-component long-period array; and the broad-band vertical seismograph - were operated continuously at the Tonto Forest Seismological Observatory from 1 July 1971 through 30 June 1972. Film and magnetic tape recordings of array data were shipped to the Seismic Data Laboratory, Alexandria, Virginia. Each week, some of these recordings were routed through the Geotech laboratories at Garland, Texas, where they were inspected for control of quality.

Modifications to the long-period array circuits, made between the 1969 and 1970 lightning storm seasons, greatly reduced lightning damage to these circuits. Similar modifications, made to one branch of the short-period array, eliminated lightning damage to amplifiers in that branch.

Operational tests were conducted with the multichannel filter (MCF), the extended long-period seismograph, a short-period borehole seismograph, a short-period five-element station, a long-period/short-period triaxial system, and a quartz accelerometer. A gravity feed chemical supply system was tested in the observatory Develocorders.

Facilities and assistance were provided to personnel from one university, and one industrial organization.

3. OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

3.1 GENERAL

Data normally were recorded continuously at the TFSO. Maintenance times, calibration times, and recording film or tape change times were staggered so that data recording was interrupted in only one system at a time.

From 1 July 1971 through 30 June 1972, the observatory was manned during an 8:00 a.m. to 5:00 p.m. shift and a 9:30 a.m. to 6:00 p.m. shift. The 8 to 5 shift was worked each Monday through Friday except holidays and was the regular work day for all personnel. The 9:30 to 6 shift was worked every day including Saturdays, Sundays, and holidays, and was staffed by one man on a rotational basis. The observatory operated unmanned from 6:00 to 8:00 a.m. MST every day. Technical work is handled by a full-time staff of four people. Secretarial work is handled by one half-time person.

3.2 SEISMOGRAPH SYSTEMS OPERATED DURING PROJECT VT/2704

3.2.1 Thirty-Seven Element Array

A 37-element array of short-period vertical seismographs (figure 2) was installed under Project VT/7702. Under Project VT/8702, this array was evaluated from the standpoint of reliability, beam-steering capability, and detection of capability. Operation of this array continued under Projects VT/9702 and VT/2704. Recording of the outer-ring channels, Z21 through Z37, was discontinued on 15 October 1971, when only one of these channels was operational and when other duties at the observatory would not permit these channels to be repaired.

3.2.2 Broad-Band Seismograph

The vertical broad-band seismograph uses a seismometer installed in the LP1 vault and a phototube amplifier installed in the CRB, and has the frequency response shown in figure 3.

3.3 STANDARD SEISMOGRAPH OPERATING PARAMETERS

The operating parameters and tolerances for the TFSO standard seismographs are shown in table 1. Frequency response tests are scheduled every 3 months, and the parameters of seismograph systems not conforming to the tolerances shown in tables 2, 3, and 4 are reset. Normalized response characteristics of TFSO standard seismographs are shown in figure 3.

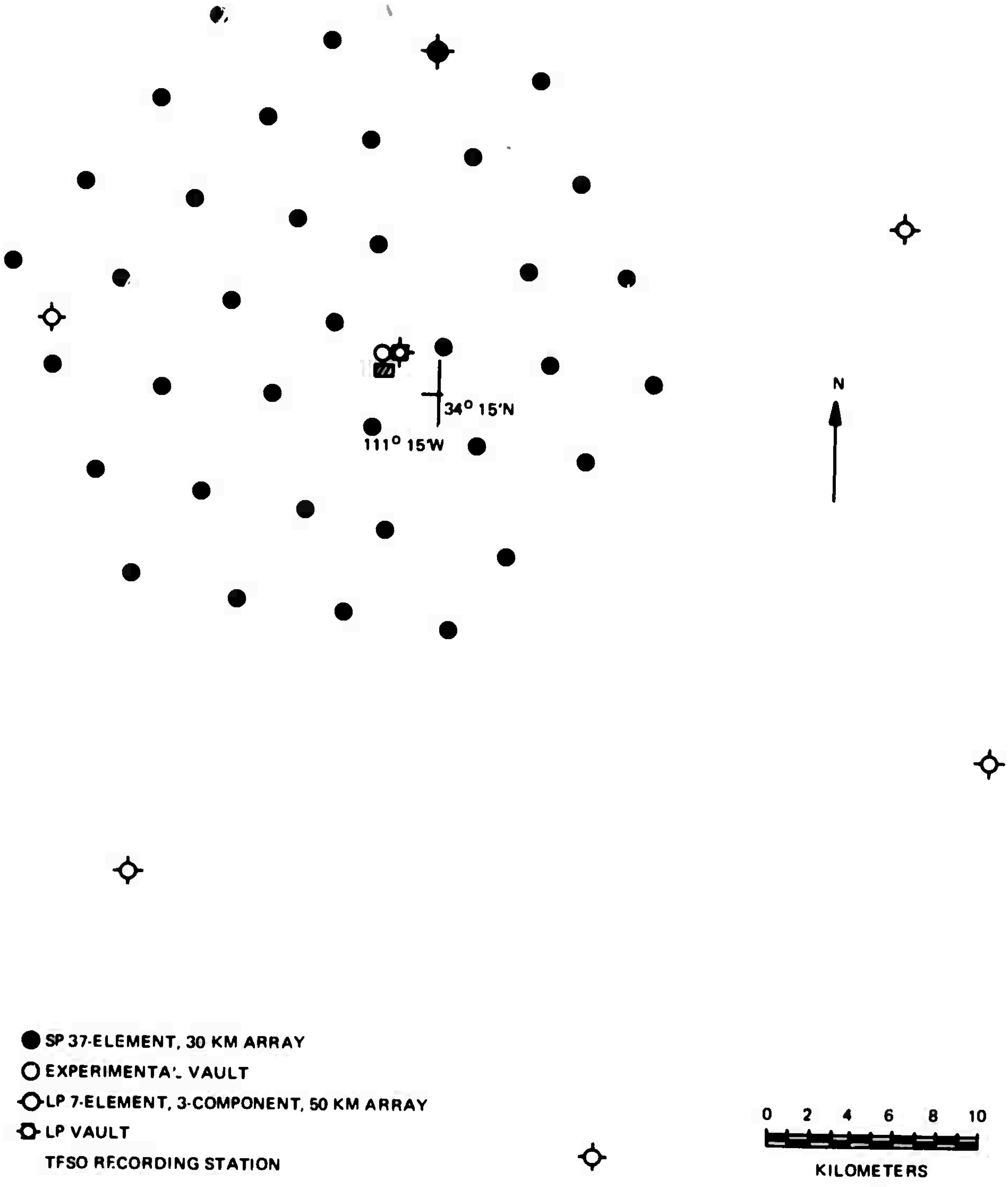

Figure 2. Vault locations in the 37-element short-period array, and the 7-element long-period array at TFSO

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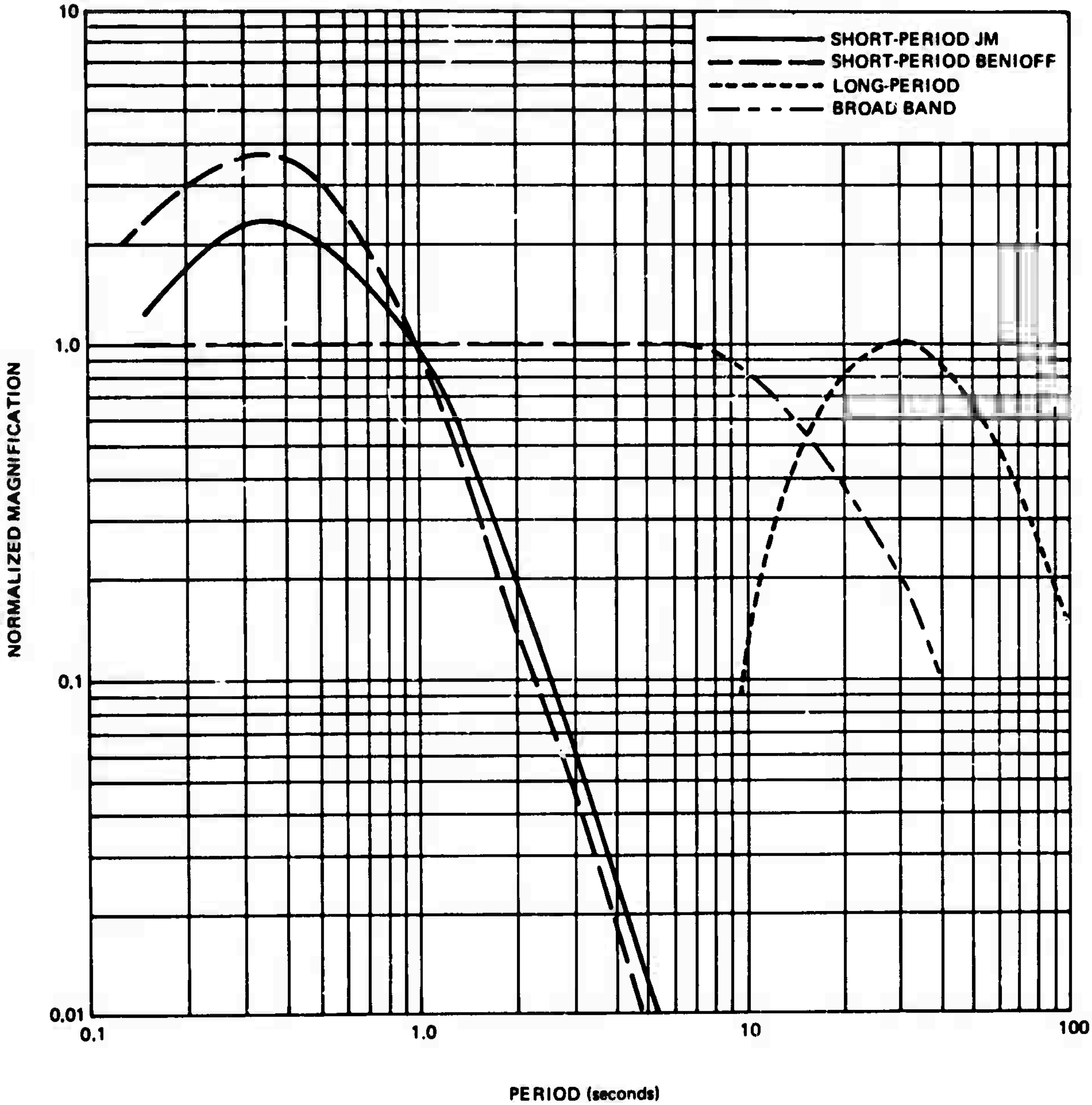

Figure 3. Normalized response characteristics of standard seismographs at TFSO

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Table 1. Operating parameters and tolerances of standard seismographs at TFSO

Seismograph				Operating parameters and tolerances				Filter and settings		
System	Comp	Type	Model	T_s	λs	T_g	λg	Model	Bandpass at 3 dB cutoff (sec)	Cutoff rate at SP side (dB/oct)
SP[a]	Z	Johnson-Matheson	6480	1.25 ±2%	0.54 ±5%	---	---	2888-1	0.2 - 1.0	6
SP[b]	Z	Johnson-Matheson	6480	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	6824-1	0.1 - 100	12
SP[b]	H	Johnson-Matheson	7515	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	6824-1	0.1 - 100	12
SP	Z	Benioff	1051	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	6824-1	0.1 - 100	12
SP	H	Benioff	1101	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	6824-1	0.1 - 100	12
SP	Z	UA Benioff	1051	1.0 ±2%	1.0 ±5%	0.75 ±5%	1.0 ±5%	---	---	--
BB	Z	Press-Ewing	SV-282	12.5 ±5%	0.45 ±5%	0.64 ±5%	9.0 ±5%	6824-7	0.05- 100	12
LP	Z	Geotech	7505A	20.0 ±5%	0.77	---	---	30024	80 - 300	6
LP	H	Geotech	8700C	20.0 ±5%	0.77	---	---	30024	80 - 300	6

KEY

SP Short period
LP Long period
UA Unamplified (i.e., earth powered)
BB Broad band

T_s Seismometer free period (sec)
T_g Galvanometer free period (sec)
λs Seismometer damping constant
λg Galvanometer damping constant

[a] 37-element hexagonal array
[b] 3 -component

Table 2. Frequency response norms and tolerances for TFSO short-period seismographs

T (sec)	f (Hz)	Tolerance (percent)	Relative amplitude Norm	Max	Min
5.0	0.2	10	0.0118	0.013	0.0106
2.5	0.4	7.8	0.0988	0.106	0.0916
1.25	0.8	5.0	0.68	0.714	0.646
1.00	1.0	0	1.00	1.00	1.00
0.67	1.5	5.2	1.55	1.63	1.47
0.50	2.0	5.1	1.97	2.07	1.87
0.33	3.0	7.3	2.30	2.47	2.13
0.25	4.0	12.2	2.05	2.30	1.80
0.167	6.0	20.3	1.38	1.66	1.10

Table 3. Frequency response norms and tolerances for TFSO long-period seismographs

T (sec)	f (Hz)	Tolerance (percent)	Relative amplitude Norm	Max	Min
100	0.01	20	0.135	0.162	0.108
80	0.0125	20	0.278	0.333	0.222
60	0.0167	15	0.485	0.558	0.412
50	0.02	15	0.644	0.741	0.548
40	0.025	10	0.874	0.961	0.787
30	0.033	5	1.03	1.082	0.978
25	0.04	0	1.00	1.00	1.000
20	0.05	5	0.825	0.866	0.784
15	0.0667	10	0.470	0.517	0.423
10	0.1	20	0.110	0.132	0.0879

Table 4. Frequency response norms and tolerances for TFSO broad-band seismographs

T (sec)	f (Hz)	Tolerance (percent)	Relative amplitude Norm	Max	Min
25.0	0.04	20	0.104	0.125	0.0832
16.7	0.06	20	0.350	0.420	0.280
12.5	0.08	15	0.775	0.891	0.659
10.0	0.1	10	0.950	1.04	0.855
5.0	0.2	5	1.00	1.05	0.950
2.5	0.4	5	1.00	1.05	0.950
1.25	0.8	0	1.00	1.00	1.00
0.625	1.6	5	1.00	1.05	0.950
0.312	3.2	10	1.00	1.10	0.900
0.156	6.4	15	0.98	1.13	0.833

3.4 DATA CHANNEL ASSIGNMENTS

Each data format recorded at TFSO was assigned a number (format number in the case of digital seismograms), and each time a new data format was established a new number was assigned. Data format change notices showing both the new data channel assignments and the previous data channel assignments were submitted to the Project Officer and were distributed to frequent users of TFSO data. The data formats recorded during Project VT/2704 are summarized in tables 5 and 6, and a key to the seismograph designators is given in table 7.

3.5 QUALITY CONTROL

3.5.1 Quality Control of 16-Millimeter Film Seismograms

Quality control checks of randomly-selected 16-millimeter film seismograms from Data Trunks 2, 4, and 8 and the associated logs were made in Garland. Items that were routinely checked by the quality control and analyst include:

a. Film boxes - neatness and completeness of box markings;

b. Develocorder logs - completeness, accuracy, and legibility of logs;

c. Film -

(1) Quality of the overall appearance of the record (for example, trace spacing and trace intensity);

(2) Quality of film processing;

d. Analysis - completeness, legibility, and accuracy of analysis sheets. Results of these evaluations were sent to the observatory for their review and comment.

3.5.2 Quality Control of Analog FM Magnetic-Tape Seismograms

Each week, quality control checks of three randomly-selected magnetic-tape seismograms are made in Garland and at TFSO to assure the recordings meet specified standards. The following items are checked:

a. Tape and box labeling;

b. Accuracy, completeness, and neatness of logs;

c. Adequate documentation of logs by voice comments on tape where applicable;

d. Seismograph polarity;

e. Level of the microseismic background noise;

Table 5. Data channel assignments for TFSO 16-millimeter film seismograms made during Project VT/2704. Dates without asterisks are start dates; dates with asterisks are stop dates.

DEVELOCORDERS
Fast speed, 30 mm/minute

Channel	Data group 7240 14 Nov 67	Data group 7242 15 Oct 72*	Data group 7295 15 Oct 72*	Data group 7299 21 Oct 70 26 Feb 71* 4 Mar 71	Data group 7301 30 Mar 71	Data group 7304 15 Oct 71
1	TCDMG	TCDMG	TCDMG	TCDMG	TCDMG	TCDMG
2	Z 1	Z 15	Z 29	BS 0	MS	Z 15
3	Z 2	Z 16	Z 30	BS 1	BFV	Z 16
4	Z 3	Z 17	Z 31	BS 2	Z60SP	Z 17
5	Z 4	Z 18	Z 32	BS 3	N60SP	Z 18
6	Z 5	Z 19	Z 33	BS 4	E60SP	Z 19
7	Z 6	Z 20	Z 34	BS 5	Z60LL	Z 20
8	Z 7	Z 21	Z 35	BS 6	N60LL	ZSH
9	Z 8	Z 23	Z 36	BS 7	E60LL	MS
10	Z 9	Z 22	Z 37	BS 8	Z60SL	WI
11	Z 10	Z 24	MS	BS 9	N60SL	Z47BF
12	Z 11	Z 25	Wi	FSH	E60SL	N47BF
13	Z 12	Z 26	Z47BF	FTH	Wi	E47BF
14	Z 13	Z 27	N47BF	WWV	WWV	WWV
15	Z 14	Z 28	E47BF	-	-	-
16	WWV	WWV	WWV	-	-	-

Table 5, Continued

DEVELOCORDERS
Slow speed, 3 mm/minute

Channel	Data group 7276 23 Jan 69	Data group 7285 21 May 69	Data group 7286 26 Jul 69	Data group 7290 19 Aug 71*	Data group 7303 19 Aug 71
1	Z4LP	Z6LP	Z2LP	TCDMG	TCDMG
2	N4LP	N6LP	N2LP	ML	ML
3	E4LP	E6LP	E2LP	E1LP	E1LP
4	Z5LP	Z7LP	Z3LP	N1LP	N1LP
5	N5LP	N7LP	N3LP	Z1LP	Z1LP
6	E5LP	E7LP	E3LP	ZXLP	ZXLP
7	ML	Z39BB	ΣZLP	ZYLP	MS
8	Wi	ML	ML	MS	ZXLL
9	WWV	Wi	Wi	ZXLL	Z1LL
10		WWV	WWV	Z1LL	N1LL
11				N1LL	E1LL
12				E1LL	Wi
13				Wi	WWV
14				WWV	
15					
16					

Table 6. Data channel assignment for TFSO FM magnetic-tape seismograms made during Project VT/2704. Dates without asterisks are start dates; dates with asterisks are stop dates

FM Tape Recorders

Channel	Data group 7239 16 Nov 67	Data group 7241 15 Nov 67	Data group 7244 11 Aug 71*	Data group 7265 25 May 68	Data group 7302 30 Mar 71
1	TCDMG	TCDMG	TCDMG	TCDMG	TCDMG
2	Z 1	Z 13	Z 25	Z1LP	Z5LP
3	Z 2	Z 14	Z 26	N1LP	N5LP
4	Z 3	Z 15	Z 27	E1LP	E5LP
5	Z 4	Z 16	Z 28	Z2LP	Z6LP
6	Z 5	Z 17	Z 29	N2LP	N6LP
7	Comp	Comp	Comp	Comp	Comp
8	Z 6	Z 18	Z 30	E2LP	E6LP
9	Z 7	Z 19	Z 31	Z3LP	Z7LP
10	Z 8	Z 20	Z 32	N3LP	N7LP
11	Z 9	Z 21	Z 33	E3LP	E7LP
12	Z 10	Z 22	Z 34	Z4LP	ΣZLP
13	Z 11	Z 23	Z 35	N4LP	
14	Z 12	Z 24	Z 36	E4LP	Z 37

Table 7. Key to the designations used in the data channel assignments at TFSO

TCDMG	Time Code Data Management Generator
Z	Amplified vertical seismograph from site identified by number
ΣT	Summation of the crossed-linear array vertical seismographs
ΣTF	ΣT filtered (UED filter)
ΣTFK	ΣT filtered (Krohn-Hite)
N	North-south horizontal seismograph
E	East-west horizontal seismograph
SP	Short-Period seismograph
WWV	Radio time from National Bureau of Standards Radio Station WWV (WWV, STS, and Voice on tape)
T	Transverse seismograph
R	Radial seismograph
BF	Seismograph using Benioff seismometer
LL	Low, low magnification (short-period) or low magnification long-period seismograph
MS	Short-period microbarograph
V	Unamplified (earth-powered) vertical seismograph
SL	Low magnification short-period seismograph
Wi	Wind indicator
BS	Beam-steered seismograph. Number refers to azimuth orientation.
HF8	High-frequency seismograph (suffix "1/10" indicates magnification one-tenth that of ZHF8 seismograph)
LP	Long-period seismograph
BB	Broad-band seismograph
Comp	Tape recorder wow and flutter compensation channel
BS	Beam steer
MCF	Multi-channel filter
FSH	Fisher process

f. Level of calibration signals;

g. Relative phase shift between array seismographs;

h. Level of system noise;

i. Oscillator alignment;

j. Quality of recorded WWV signal where applicable;

k. Time-pulse carrier;

l. Binary-coded digital time marks.

3.5.3 Quality Control of ASDAS Magnetic-Tape Seismograms

Quality control checks of ASDAS tapes are made routinely. At present, one tape from each of the two transports is checked weekly for the following items:

a. Neatness and accuracy of the associated logs;

b. Polarity errors;

c. Recording level of each channel;

d. Fidelity of reproduction;

e. Presence of header record and correct record length;

f. Tape parity errors;

g. Timing information.

3.5.4 Quality Control of DGRDAS Magnetic-Tape Seismograms

Quality control checks of DGRDAS tapes are made routinely. At present, one tape is checked each week for items listed under section 3.5.3 and, in addition, for the following items:

a. Field transmission parity errors;

b. Central digital system parity errors;

c. Gain code errors.

3.6 COMPLETION AND SHIPMENT OF DATA

Two ASDAS digital tapes were shipped each week from TFSO to the Garland laboratory for quality control. All other digital tapes were held at the observatory for a period of about 8 weeks and then were recycled if not requested by the SDL.

Five analog FM magnetic-tape units were used until 11 August 1971 to record data for the AFTAC VELA Seismological Center (NYV). After that date four tape machines were used. FM tapes for six days of each week were sent directly to SDL. The tapes for the seventh day were sent to our Garland laboratory for quality control inspection, then forwarded to SDL.

All Develocorder (16-millimeter film) seismograms, except quality control copies, were routinely shipped to SDL. One seismogram for each Develocorder was sent each week to our Garland, Texas, laboratory for quality control, then forwarded to SDL.

Copies of calibration and operational logs accompanied all data shipments.

3.7 CALIBRATION OF TEST EQUIPMENT

Test instruments were routinely calibrated at TFSO during the contract period and calibration logs were maintained for all such instruments. All calibrations were referred to Eppley standard cells which, in turn, were periodically certified to deviate less than 0.001 percent from standards maintained by the National Bureau of Standards.

3.8 EMERGENCY POWER GENERATOR

During this report period, the emergency power generator was operated a total of 22.1 hours. It was operated 15.8 hours during loss of commercial power, and 6.3 hours during tests under full load.

3.9 SECURITY INSPECTION

Security inspections were conducted on 27 October 1971 by Mr. Ken Ozbolt, Industrial Security, Phoenix, Arizona, and on 2 February 1972 by Mr. M. Craig, Chief, Industrial Security, Phoenix, Arizona. All phases of the TFSO security program were found to be in good order.

A security inspection, scheduled for 23 June 1972, was postponed until July because of floods that followed heavy rains in the Phoenix area.

3.10 GOVERNMENT PROPERTIES

Mr. L. R. Madden and Mr. P. Johnson, of the DCASD, Phoenix, Arizona, visited the observatory on 24 August to conduct an inspection of all government property control procedures.

3.11 FACILITY MAINTENANCE

The TFSO facilities were maintained in accordance with sound industrial practicies throughout the report period. This work included pest extermination, fire extinguisher inspection, work area cleaning, and lubrication and cleaning of the heating and air conditioning equipment.

3.12 SPIRAL-4 TRANSMISSION CIRCUITS

A total of 67 spiral-4 transmission circuit failures were detected and repaired between 1 July 1971 and 30 June 72. The failures were caused by vandals who shot into cables and splice boxes, or who chopped up cables with a sharp implement; by road construction machinery that accidentally cut cables; by lightning that damaged cables and cable hocks; and by cable deterioration that lowered insulation resistance among conductors and ground. Repairs were accomplished by replacing cable sections, splicing cut sections, replacing burned loading coils, cleaning carbonized hock contacts, and repairing damaged splice boxes. Table 8 shows a breakdown of the failures and repairs during each quarter of the report period.

Table 8. Spiral-4 transmission circuit failures and repairs

	Number of failures in each quarter				
Cause of failure	July - Sept. 71	Oct. - Dec. 71	Jan. - Mar. 72	Apr. - June 72	Totals
Vandalism	1	2	3	3	9
Lightning	9	7	0	5	21
Accidental cut	5	4	2	4	15
Cable deterioration	0	3	14	5	22
Totals	15	16	19	17	67
Repair technique	Number of repairs in each quarter				
Replace cable section	9	10	15	11	45
Splice cable	4	5	2	3	14
Replace loading coil	1	1	0	2	4
Clean hock	1	0	1	0	2
Repair splice boxes	0	0	1	1	2
Totals	15	16	19	17	67

4. MAINTENANCE AND MODIFICATION OF TFSO INSTRUMENTATION

4.1 LIGHTNING PROTECTION

4.1.1 Review of Effectiveness

The monthly distribution of lightning storms in the TFSO area during the calendar year 1971 followed the same general pattern as it had during the previous three years. There was a small incidence of lightning during the winter and spring months, and a large incidence during July, August, and September. Lightning was observed during 78 days, an increase over the previous years. These data, together with data for the first six months of 1972, are shown in figure 4. Note that the 1972 lightning season started early and that its pattern of storm distribution will be significantly different from those observed during the previous four years.

Data concerning solid-state amplifiers damaged by lightning during the years 1968 through 1971 are summarized in table 9. In general, the incidence of damage to LP amplifiers during 1971 was approximately the same as during 1970. The sharp reduction of damage to SP amplifiers - from 43 in 1970 to 17 in 1971 - reflects, in part, the smaller number of channels that were maintained operational during 1971, and in part, the improved lightning protection provided by modified circuits in power branch no. 2. It should be noted that because priority was given to the maintenance of channels Z1 through Z20, the other channels, Z21 through Z37, were not repaired as they became inoperative. By 15 October 1971, when recording of channels Z21 through Z37 was discontinued, only one of these channels was still operational. Because components in these channels were not repaired, the amplifier failure records do not reflect these failures.

Table 9. Solid-state amplifiers damaged by lightning

Amplifier	1968	1969	1970	1971
	Number of failures			
SP, Model 25220	44	25	43	17
LP, Model 28470	25	36	10	12
	Number of lightning days			
	38	58	63	78
	Number of failures per lightning day			
SP amplifiers	1.16	0.43	0.68	0.24*
LP amplifiers	0.66	0.62	0.16	0.15

*Maintenance in 17 of the 37 SP channels was not performed for more than 6 months of 1971.

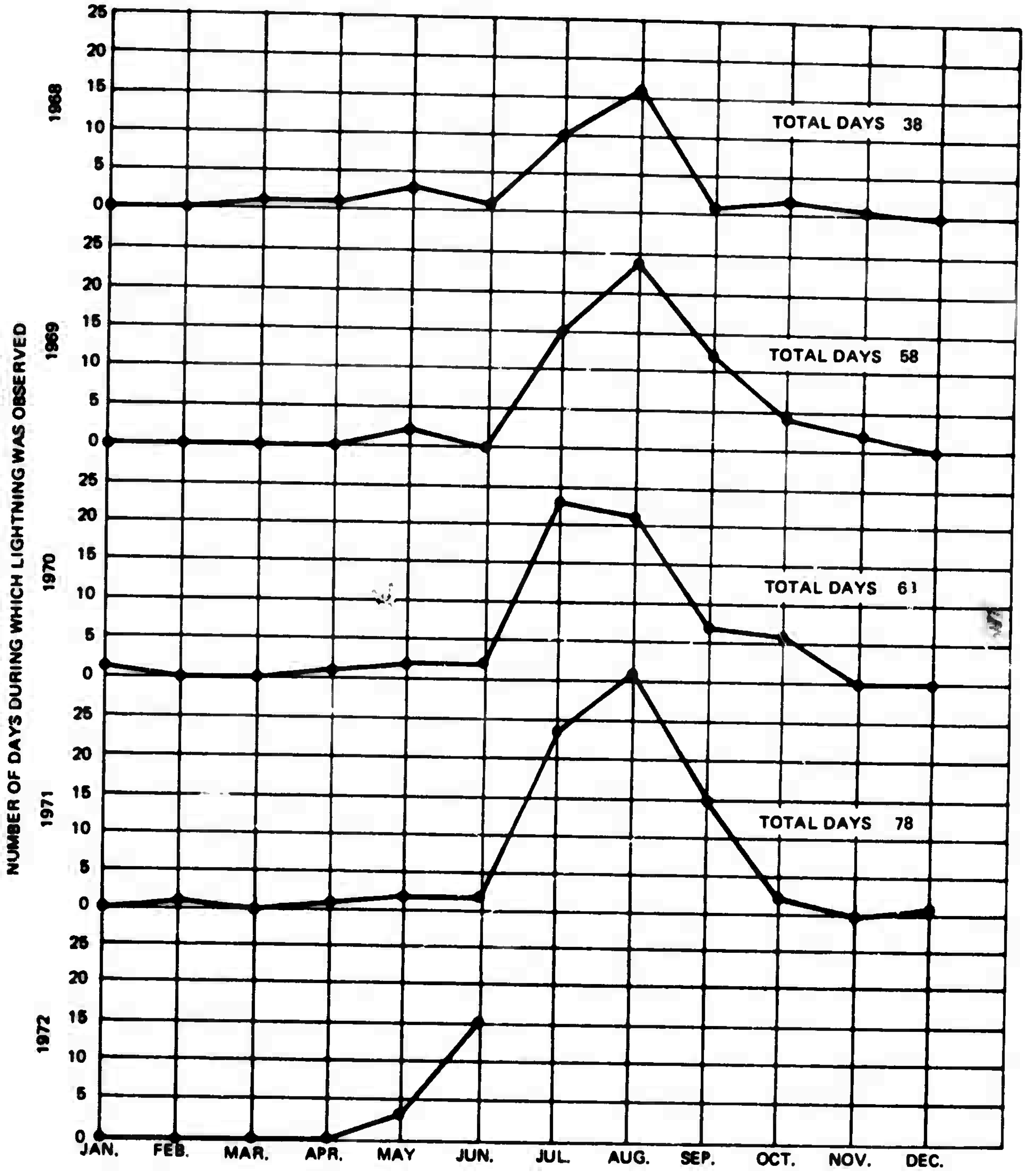

Figure 4. Monthly distribution of lightning storms in TFSO area

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4.1.2 Test of Experimental SP Protection Circuit

Operational tests were continued into August 1971 to determine the protective capabilities of the experimental lightning protection circuit installed on 28 January 1971 in power branch no. 2 of the short-period seismograph array. By mid-August, operational data showed that the experimental circuit, which added ground-referenced diode protection to the channels Z12 and Z20, but left Z11 and Z13 through Z19 unchanged as controls, could be operated without introducing noise into the data circuits nor unbalance in the power circuits. Furthermore, 7 of the 9 amplifiers in the unchanged circuits were damaged by lightning, whereas neither the Z12 amplifier nor the Z20 amplifier was damaged, even though the cable to Z20 was struck by lightning and required replacement. Following a review of these data with the Project Officer and with his approval, work was undertaken to add ground reference diode protection to channels Z11 and Z13 through Z19. Completion dates for these modifications, and amplifier failures that occurred before and after the modifications, are listed in table 10. Note that there were no amplifier failures after the power circuits were modified, even though there was unusually high lightning activity during May and June 1972. Three amplifiers were lost in the unmodified SP channels Z1 through Z10 during these 2 months. On the basis of this information, it is concluded that the power circuit modifications used on channels Z11 through Z20 are effective in reducing lightning damage to amplifiers. It is recommended that similar modifications be made to power circuits in the SP channels Z1 through Z10.

4.2 SHORT-PERIOD ARRAY

Because the observatory operating staff was very small (limited by available funding), maintenance work was carried out on a priority basis. The long-period array was given first priority, and the short-period array second priority. Within the short-period array, channels Z1 through Z20 were given priority over channels in the outer rings.

4.3 LONG-PERIOD ARRAY

4.3.1 General

Most of the long-period array maintenance effort was directed towards the repair and replacement of spiral-4 cable assemblies, their loading coils and splice boxes. A much smaller effort was required for the replacement and repair of amplifiers, the recentering of masses on seismometers, and the replacement of blown power fuses.

On 26 November 1971, Mountain Bell changed the 2-wire telephone circuit to the LP2 site to a 4-wire circuit. The new circuit, installed at no charge, permitted transmission of both data and calibrations via telephone circuits. Before the change, calibrations were transmitted to LP2 via the Z22 calibration cable, which is no longer in service.

Table 10. Short-period array amplifier failures during report period

Channel	1971						1972					
	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
1												
2												
3												
4		X										X
5												
6		X										
7											X	
8												
9											X	
10	XX	X										
11	X	X	XM									
12	*											
13	X								XM			
14	X		M									
15	X	X	M									
16			M									
17	X		XM									
18				XM								
19					M							
20	*											

KEY

X - One amplifier failure
M - Power circuit modified
* - Power circuit modified, Feb 71

4.3.2 Relocation of LP6

Engineering Change Proposal No. 1, which describes the work required to relocate field site LP6, and indicates the need for this change, was submitted on 22 October. Since that time we have assisted the Project Office in formulating and coordinating plans to accomplish the relocation. Meetings were held with representatives of the United States Forest Service (USFS), the Corps of Engineers, and the Project Office at various times throughout the report period. Our Engineering Change Proposal No. 1, P-1960, was negotiated on 25 February 1972, but permission to proceed with the work had not been received from the USFS by the end of this report period.

4.3.3 LP5 Power Generator

Routine maintenance, including changes of oil, oil filter, and air cleaner, and filling of water, oil, and fuel tanks was performed every 3 months.

4.4 ASTRODATA SEISMIC DIGITAL ACQUISITION SYSTEM

4.4.1 Recording Time Schedule

The Astrodata Seismic Digital Acquisition System (ASDAS) was operated from 0000Z through 0430Z and 1425Z through 2330Z on Monday through Friday except on holidays, and was operated from 0000Z through 0430Z and 1630Z through 2330Z on Saturdays, Sundays, and holidays.

4.4.2 Recording Formats

Data were recorded on magnetic tape by the ASDAS using the format shown in table 11. This format was not changed when the operation of short-period array channels Z21 through Z37 was stopped on 15 October.

4.4.3 Operation and Maintenance

The ASDAS was operated routinely throughout the report period. Maintenance performed included routine cleaning, repairs and adjustments. Drive belts, motor brushes, read cards, brake pins, vacuum motors, fuses, and photosense lamps were typical of the components that failed and required replacement. In addition, the drag brake and the active filter power supplies, were repaired, and the supply reel lock hubs were adjusted.

4.5 DIGITAL GAIN-RANGING DATA ACQUISITION SYSTEM

The digital gain-ranging data acquisition system was operated routinely throughout the report period. Its operation was interrupted only for routine cleaning, and for the replacement of a parity bit generator, whose failure caused the generation of field transmission parity errors on channel 3.

On 16 December, the start-up procedure was modified to improve transport starting reliability and to eliminate the generation of a word length error flag during start-up.

Table 11. Astrodata Seismic Digital Acquisition System recording format used at the TFSO from 1 July 1971 through 30 June 1972

Format No. 19

Channel	Data	Channel	Data
1	Z 1	25	Z 25
2	Z 2	26	Z 26
3	Z 3	27	Z 27
4	Z 4	28	Z 28
5	Z 5	29	Z 29
6	Z 6		Z 30
7	Z 7	31	Z 31
8	Z 8	32	Z 32
9	Z 9	33	Z 33
10	Z 10	34	Z 34
11	Z 11	35	Z 35
12	Z 12	36	Z 36
13	Z 13	37	Z 37
14	Z 14	38	Z1LP
15	Z 15	39	Z2LP
16	Z 16	40	Z3LP
17	Z 17	41	Z4LP
18	Z 18	42	Z5LP
19	Z 19	43	Z6LP
20	Z 20	44	Z7LP
21	Z 21	45	ZXLP
22	Z 22	46	BS 9
23	Z 23	47	FSH
24	Z 24	48	STS

5. INSTRUMENT EVALUATION

5.1 MULTICHANNEL FILTER

The multichannel filter (MCF) was inoperative from 18 April until 15 July 1971, when repairs were completed to circuits in the paper recorder, the auxiliary processor and the memory. During the remainder of the report period, other maintenance was performed, including replacement of the RFI filter, and repairs to the +5 volt power supply and the paper tape reader.

From 15 July through 17 August, the MCF operated with the data format shown in table 12. The MCF was not operated from 17 August through 16 November 1971, and from 2 February through 20 April 1971 because too few short-period array channels were functional to justify its operation during those periods. From 17 November 1971 through 1 February 1972 and from 21 April through 30 June 1972, the MCF was operated using the data format shown in table 12. Samples of recordings made during these periods are shown in figures 5 through 7.

5.2 EXTENDED LONG-PERIOD SEISMOGRAPH

Operation of the extended long-period seismograph was resumed on 6 July 1971. The channel, designated ZXLP, was recorded on Develocorder film at a magnification of 140K (at X10 view) and on digital magnetic tape. Figures 8 through 10 show typical recordings of data from this channel.

5.3 GRAVITY FEED CHEMICAL SUPPLY SYSTEM

On 9 April 1971, following 5 months of failure-free continuous operational testing of two experimental gravity feed chemical supply systems, the peristaltic pumps on all operational Develocorders at the observatory were replaced with gravity feed systems. Figure 11 shows a schematic of the system and figure 12 shows one system installed on a Develocorder. Initially, the performance of these systems was excellent, but it deteriorated gradually until failures became a daily occurrence.

In general, the systems failed by interrupting or greatly reducing the flow of fixer in the short-period Develocorders. There were no failures in the systems that furnished fixer in the long-period Develocorders, nor were there any failures in the systems that furnished developer to either the long- or short-period Develocorders.

Table 12. Multichannel filter formats used

15 July through 17 August 1971

Channel identification	Azimuth from TFSO	Distance from TFSO	Apparent velocity (km/sec)
BS 0	0°	70°	18
BS 1	315°	70°	18
BS 2	270°	70°	18
BS 3	225°	70°	18
BS 4	180°	70°	18
BS 5	135°	70°	18
BS 6	90°	70°	18
BS 7	45°	70°	18
BS 8	ALL	180°	Infinite
BS 9	336°	40°	13.5
MCF 0	336°	40°	(23 point filter)
Fisher	336°	40°	

17 November 1971 through 1 February 1972 and 21 April through present

Channel identification	Azimuth from TFSO	Distance from TFSO	Approximate location	Apparent velocity (km/sec)
BS 0	0°	70°	Novaya Zemlya	18
BS 1	315°	70°	Kurile Islands	18
BS 2	270°	70°	Marshall Islands	18
BS 3	225°	70°	Cook Islands	18
BS 4	180°	70°	Easter Islands	18
BS 5	135°	70°	Arica, Chile	18
BS 6	90°	70°	Cape Verde Basin	18
BS 7	45°	70°	Portugal	18
BS 8	Any	180°	East Crozet Basin	∞
BS 9	313°	70°	Kurile Islands	18

Fisher - Beamed for 313° azimuth 70° distance
Fisher threshold set to 240_8 - 206_{10}

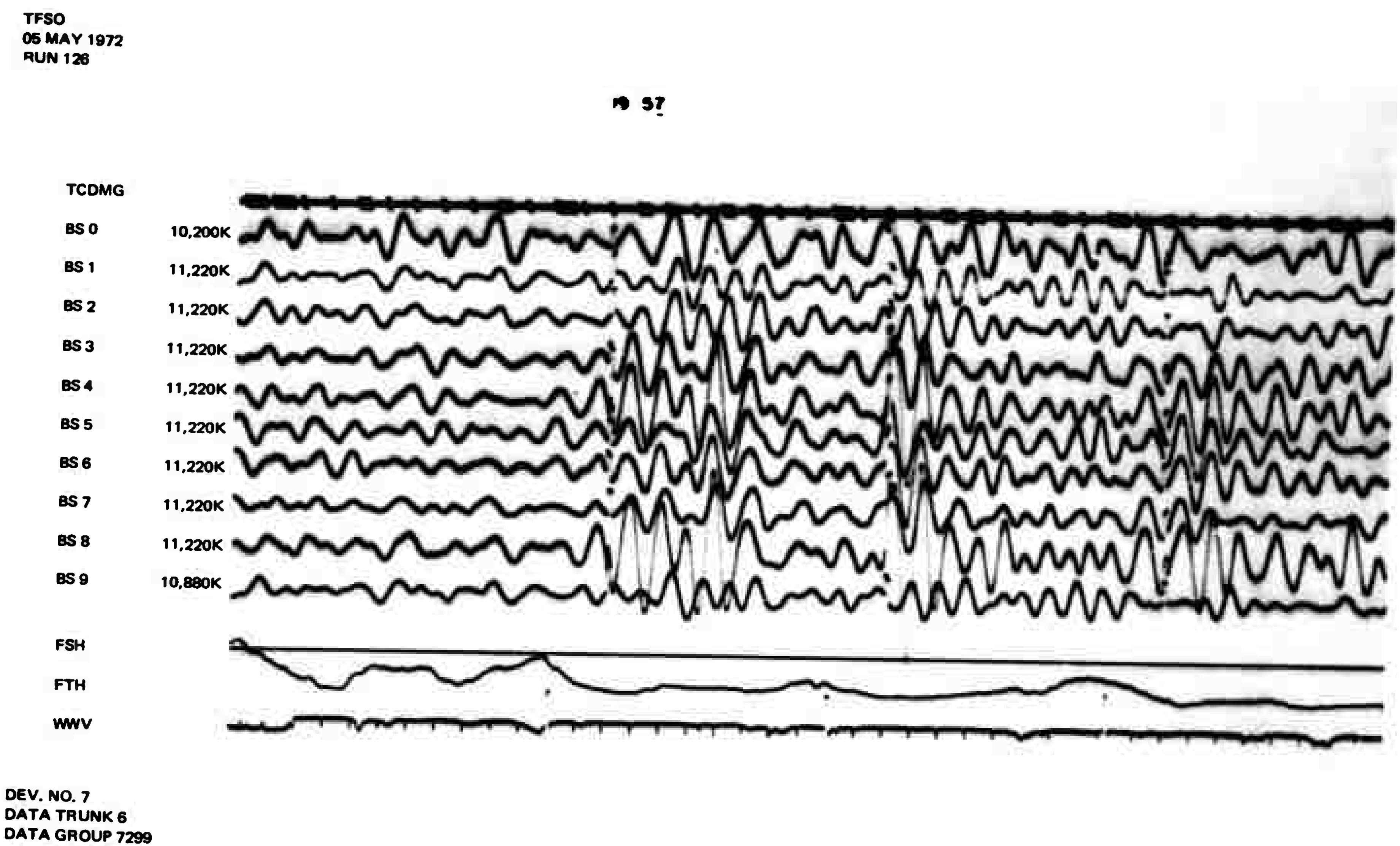


Figure 5. Short-period seismogram exhibiting response of beam-steered MCF to a low level teleseismic event of unknown origin (X10 enlargement of a 16-millimeter film)

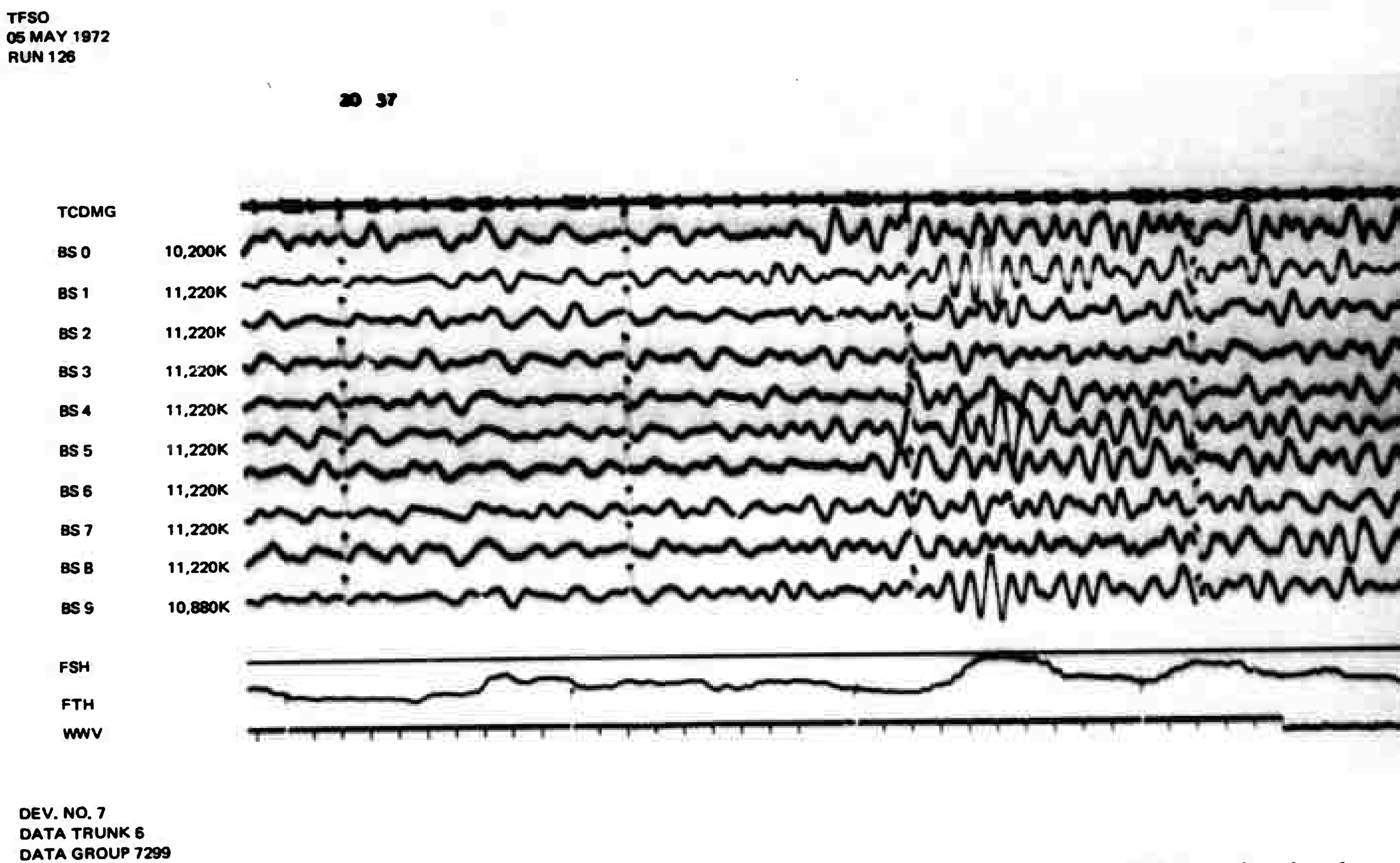


Figure 6. Short-period seismogram exhibiting response of beam-steered MCF to a low level teleseismic event of unknown origin (X10 enlargement of a 16-millimeter film)

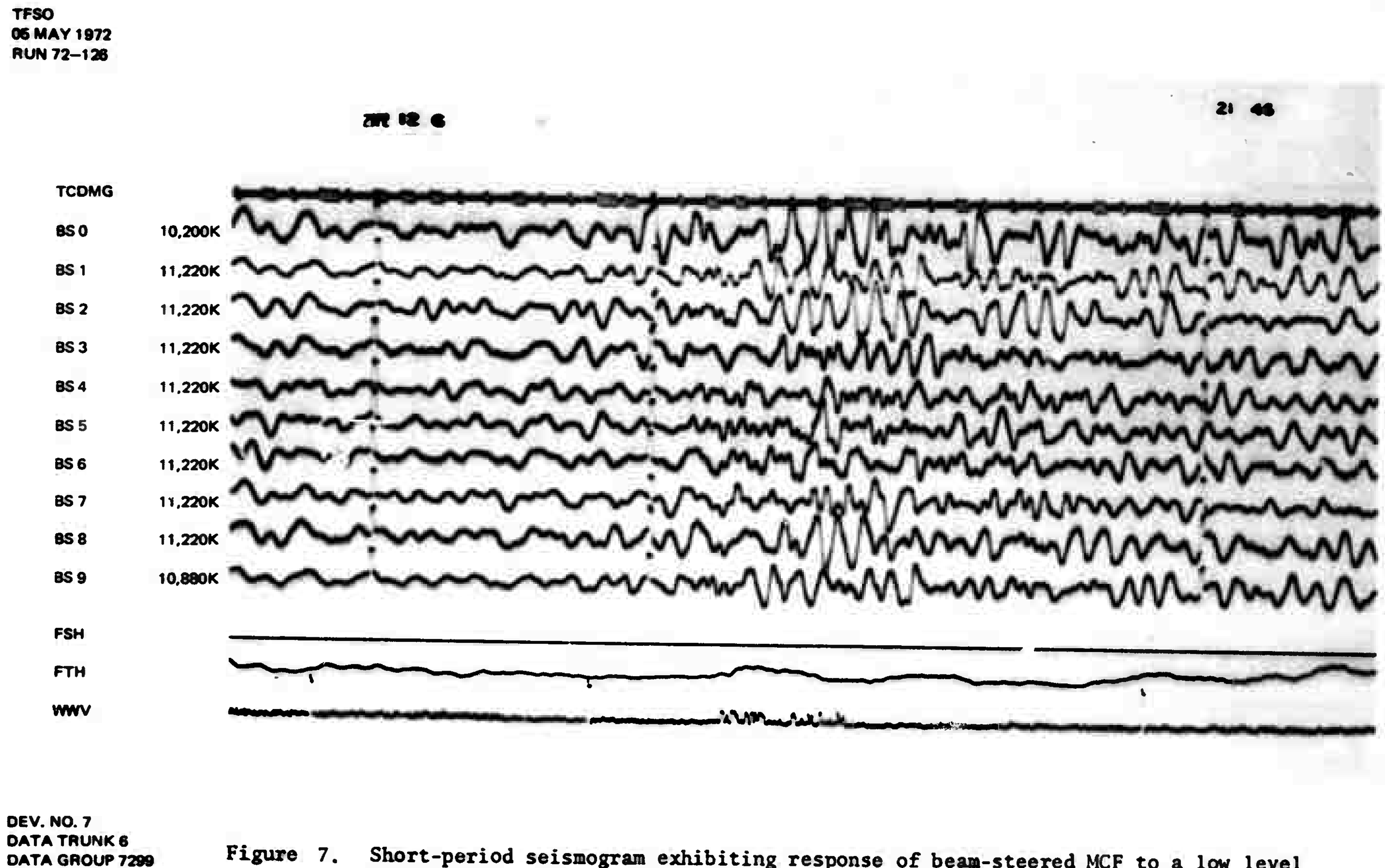


Figure 7. Short-period seismogram exhibiting response of beam-steered MCF to a low level teleseismic event of unknown origin (X10 enlargement of a 16-millimeter film)

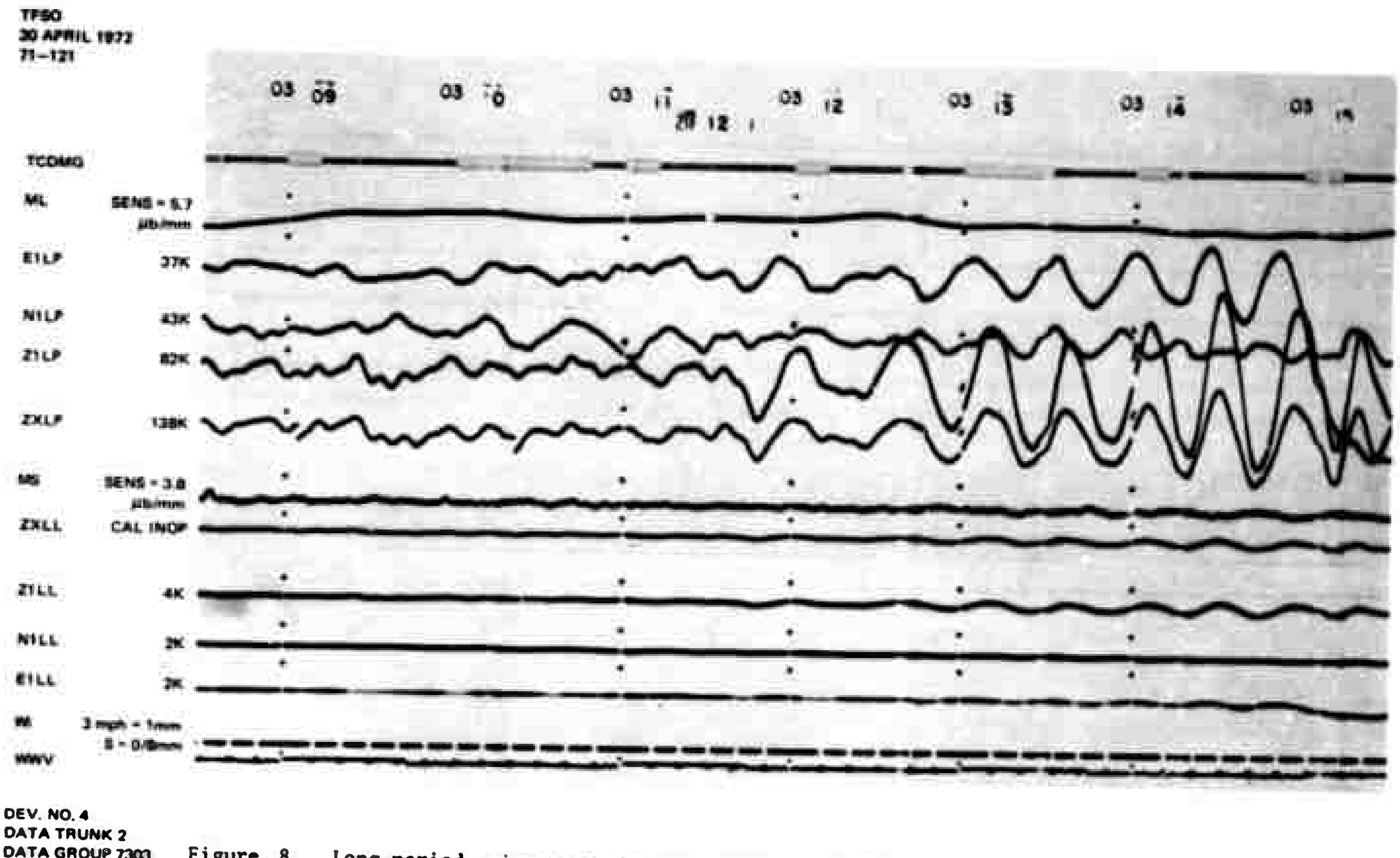
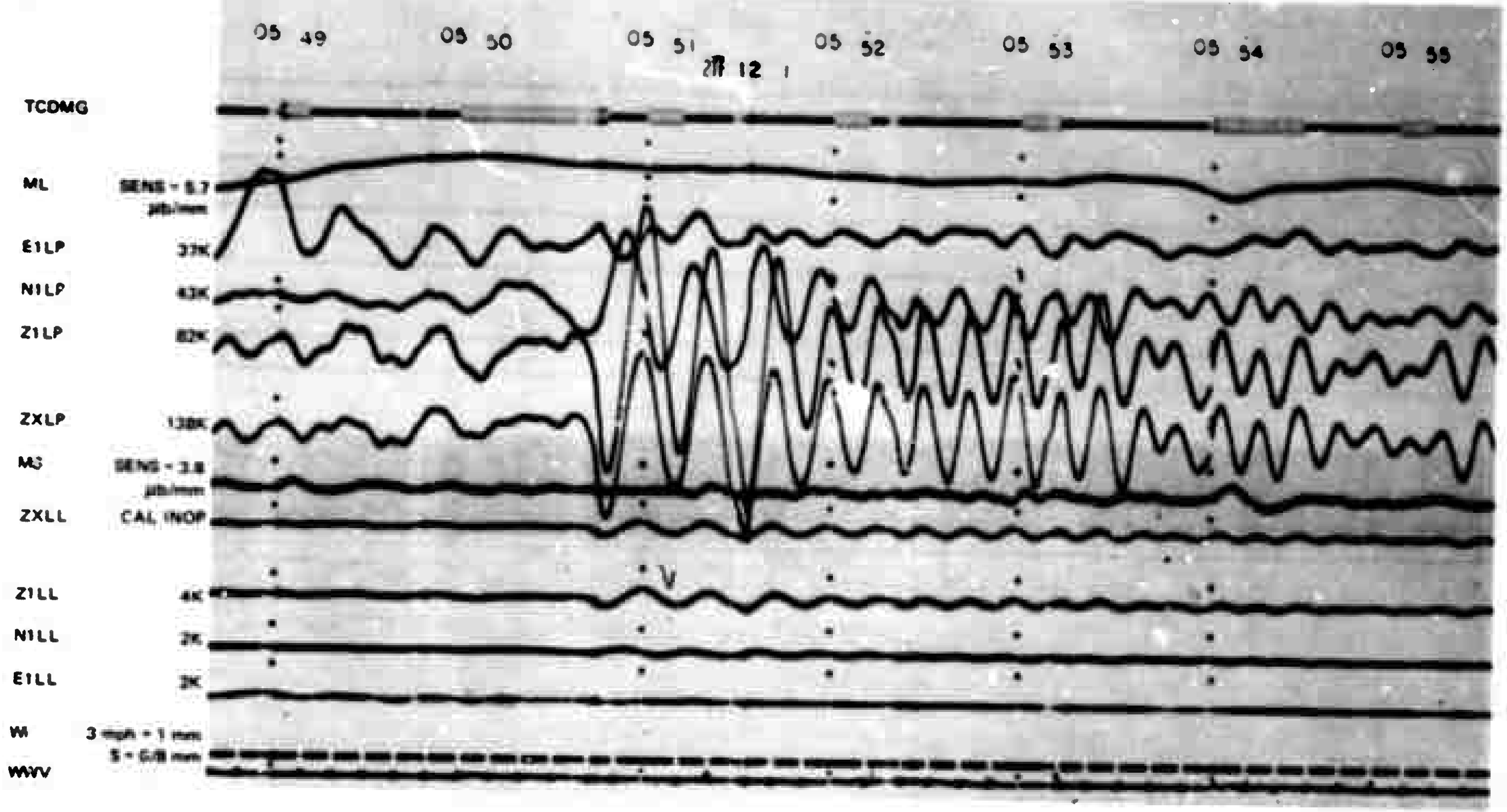


Figure 8. Long-period seismogram showing response of ZXLP to seismic event of unknown origin. Some waveform distortion is present because of momentary hesitations in film movement (X10 enlargement of 16-millimeter film)

TFSO
30 APRIL 1972
72–121



DEV. NO. 4
DATA TRUNK 2
DATA GROUP 7303

Figure 9. Long-period seismogram showing response of ZXLP to seismic event of unknown origin. Some waveform distortion is present because of momentary hesitations in film movement (X10 enlargement of 16-millimeter film)

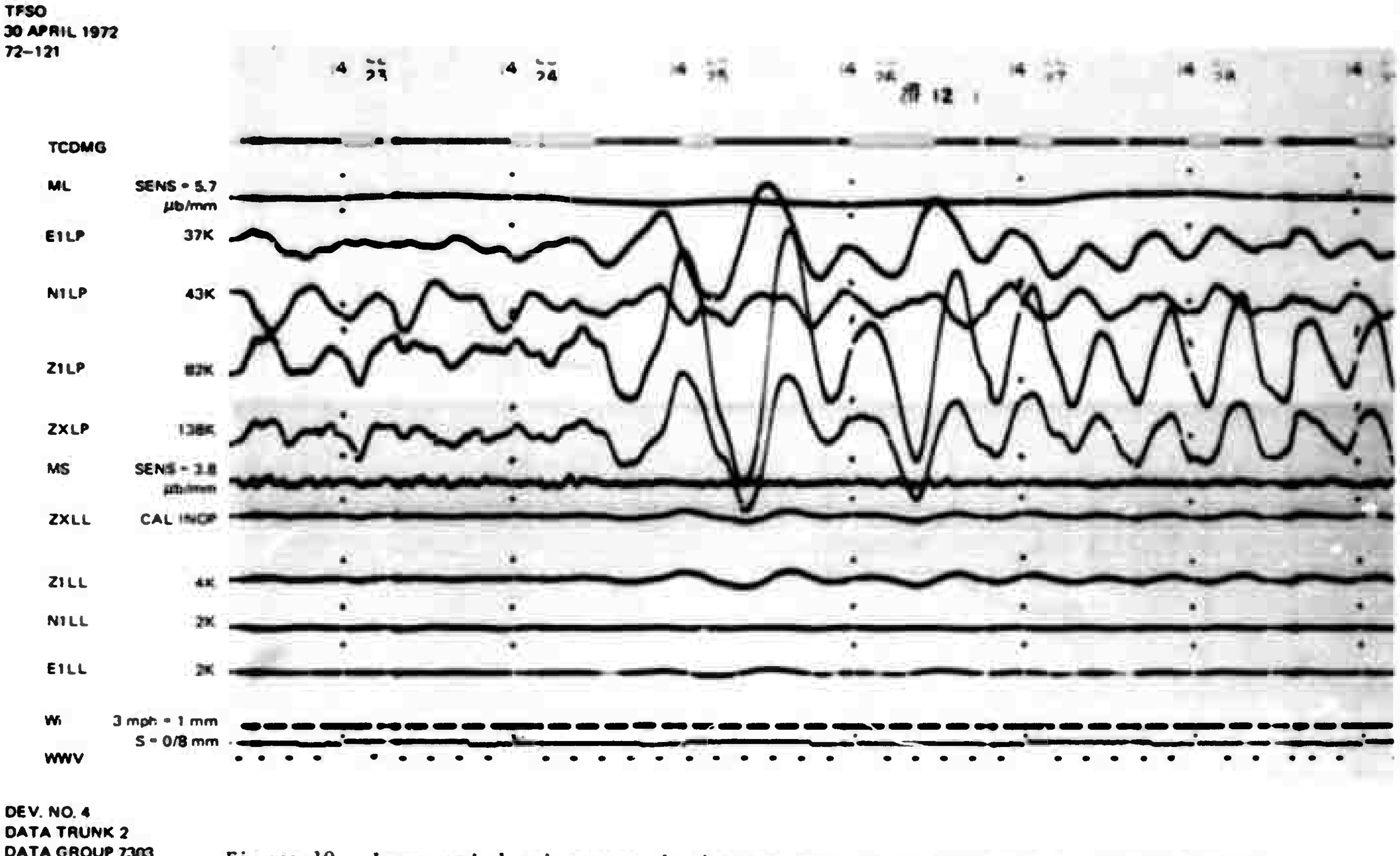


Figure 10. Long-period seismogram showing response of ZXLP to seismic event of unknown origin. Some waveform distortion is present because of momentary hesitations in film movement (X10 enlargement of 16-millimeter film)

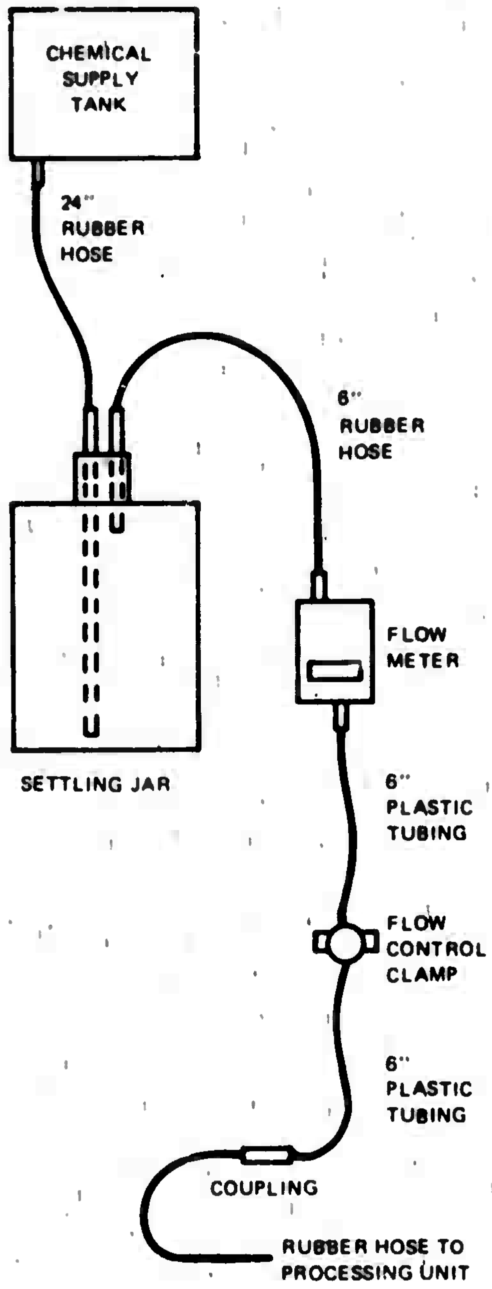


Figure 11. Schematic diagram for gravity feed chemical supply system used on TFSO Develocorders, two such channels are required for each Develocorder

G 6924

Figure 12. Typical gravity feed chemical supply system used on TFSO Develocorders

G 6925

A variety of system modifications were tried in attempts to restore reliable operation. These included different chemical flow rates, different fixers, and different control and indicator components. It was found that the Kodak Rapid Fix, which had been used with the peristaltic pump chemical feed system, produced a precipitate that apparently interfered with the operation of the gravity feed system. Performance of the system was greatly improved when G E Supermix Fix was used in place of the Rapid Fix, but a few failures continued to occur. In the middle of June 1972, the gravity feed systems were completely rebuilt using new, clean materials, and the chemical handling procedures were revised to eliminate the possibility that contaminants might be introducted into the chemical solutions. Since that time there have been no failures in the chemical supply system of any Develocorder.

We wish to acknowledge the information and suggestions given by personnel of the Large Aperture Seismic Array in Montana and to thank them for their help in making the gravity feed system work.

5.4 LP/SP TRIAXIAL SYSTEM

Testing of the LP/SP triaxial system, started in February 1971 under Contract F33657-70-C-0733 and reported upon in TR 71-18[1], was continued during this report period.

The long-period triaxial system was operated routinely from 29 September to 14 October with magnifications of the coordinate-transformed channels (ZTLP, NTLP, and ETLP) adjusted to equal those of the corresponding LP1 channels (Z1LP, N1LP, and E1LP). The vertical channel magnifications were set to approximately 50K, the horizontals to approximately 25K.

Operation testing of the system was resumed during January 1972 with the ZTSP, NTSP, and ETSP channel magnifications set to 1200K. During February, filter settings were adjusted to bring the triaxial system frequency response closer to the TFSO short-period system response and the ZTSP, NTSP, and RTSP channel magnifications were reduced to 965K. The triaxial system was deactivated on 13 March and sensor modules were shipped to McClellan AFB on 15 March.

Figures 13 through 16 show typical recordings made during these tests.

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[1]Technical Report No. 71-18, Operation of the Tonto Forest Seismological Observatory, Final Report, Project VT/0704

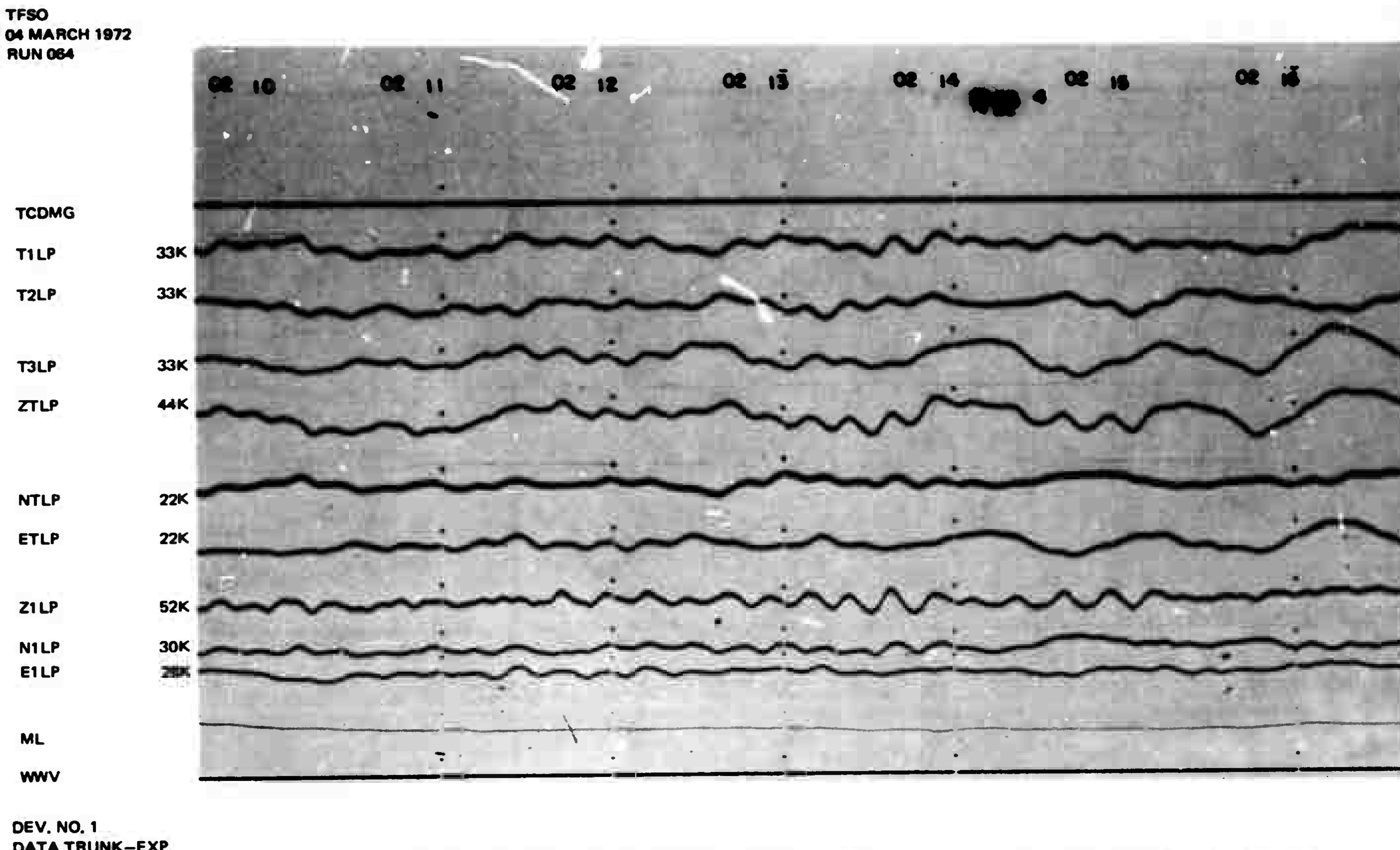

Figure 13. Long-period seismogram showing response of triaxial system to typical background noise during quiet period. Modules were oriented for normal operation 120° apart with T1 aligned north-south (X10 enlargement of 16-millimeter film)

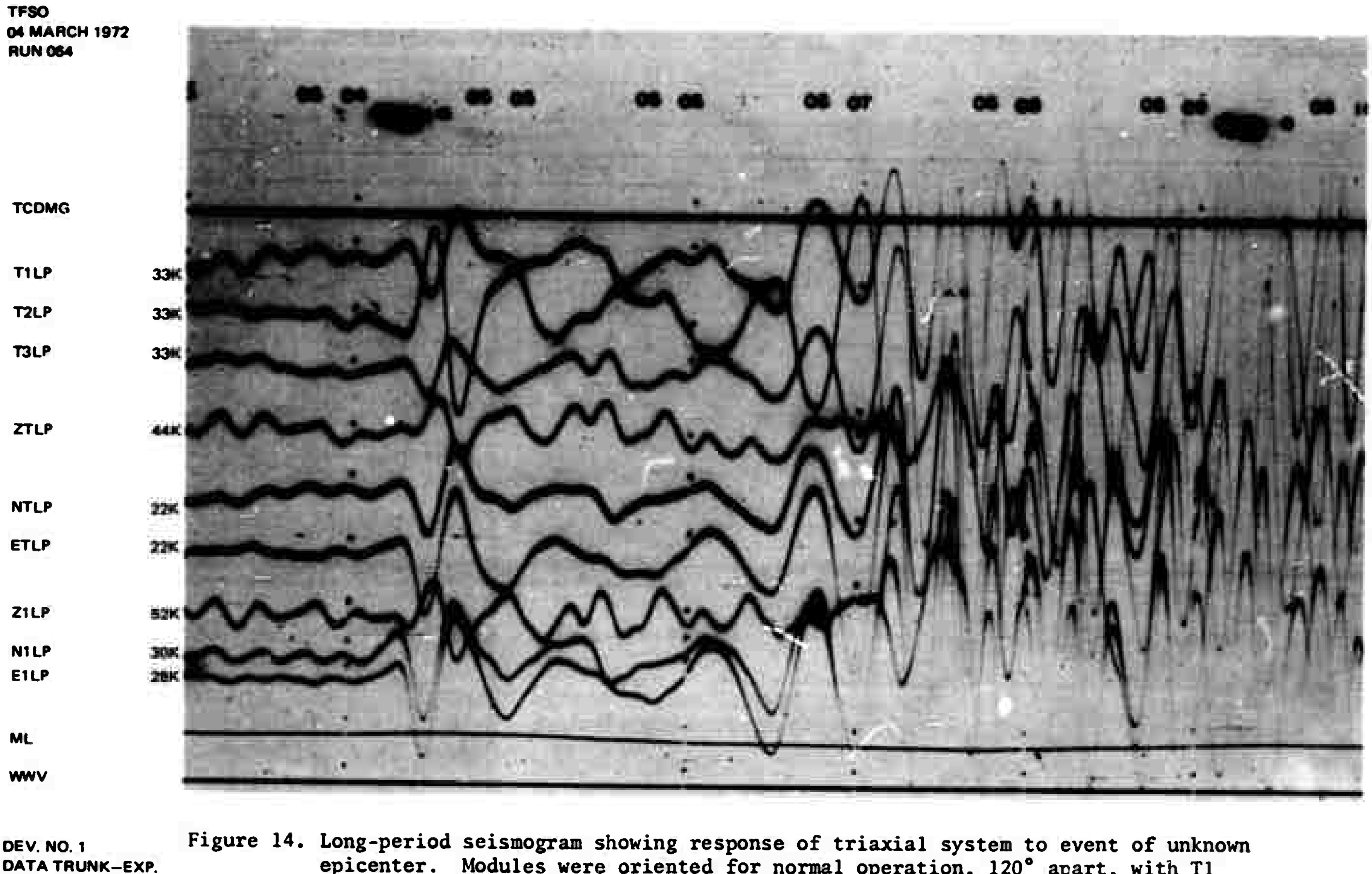

Figure 14. Long-period seismogram showing response of triaxial system to event of unknown epicenter. Modules were oriented for normal operation, 120° apart, with T1 aligned north-south (X10 enlargement of 16-millimeter film)

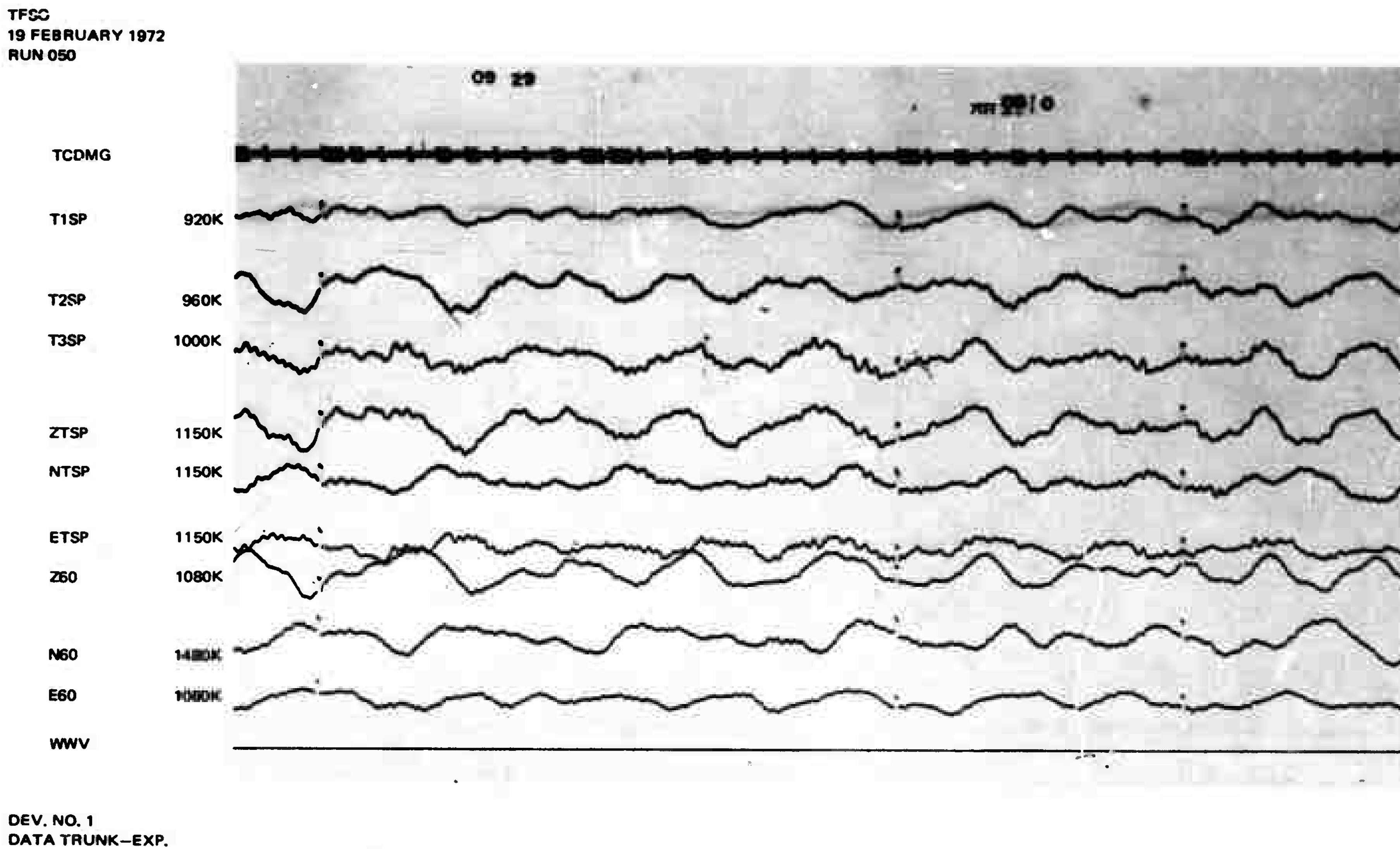

Figure 15. Short-period seismogram showing response of triaxial system to typical background noise during quiet period. Modules were oriented for normal operation, 120° apart with T1 aligned north-south (X10 enlargement of 16-millimeter film)

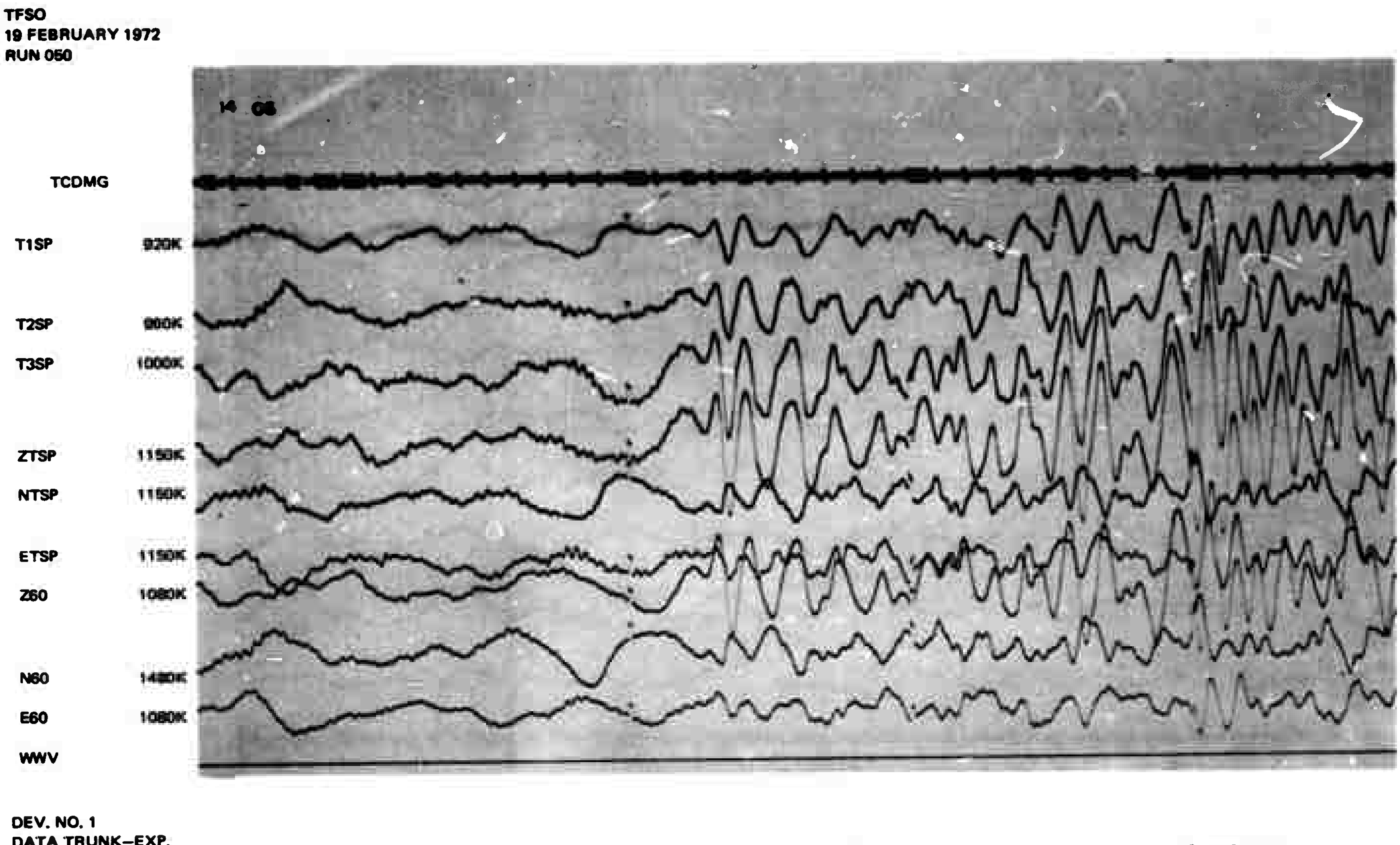

Figure 16. Short-period seismogram showing response of triaxial system to event of unknown epicenter. Modules were oriented for normal operation 120° apart with T1 aligned north-south (X10 enlargement of 16-miliimeter film)

5.5 SHORT-PERIOD SHALLOW-BOREHOLE SEISMOGRAPH

The shallow-borehole seismometer was raised to the surface for maintenance on 9 July. After repairs were made to its leaky cable, the seismometer was lowered to a depth of 25 feet and its operational parameters were checked. After these were found to be within acceptable tolerances, the seismometer was lowered to a depth of 171 feet, where it was rechecked and put into operation. The shallow-borehole seismograph has been operating routinely since 21 July 1971.

5.6 SHORT-PERIOD FIVE-ELEMENT STATION

Operation of this station was continued through the 1971 summer lightning season to determine the effectiveness of its lightning protection circuits. The station was operated routinely until 17 July, when the automatic calibrator became inoperative. After repairs were made on 28 July, the station magnification was checked and found to be 20 percent low, indicating that one element might be inoperative. However, all elements were calibrated separately and were found to operate properly. The automatic calibrator output current was found to have changed value and was readjusted.

It was concluded that the lightning protection circuits are acceptable: the five-element station was not damaged even though lightning storms are known to have occurred during 73 days of its operational tests.

Recording of data from the station was stopped on 14 October, and the radio telemetry and other Remote Operating Facility (ROF) equipment was removed from the field. All five borehole seismometers, their remote terminal units, and interconnecting cables were left as originally installed.

5.7 QUARTZ ACCELEROMETER

On 10 February, Engineering Change Proposal No. 2 to Contract F33657-72-C-0013 was submitted. Identified as Geotech Proposal No. P-1976, and entitled Evaluate Quartz Accelerometer, this proposal outlined the work that would be undertaken to evaluate the quartz accelerometers designed and built by Drs. Barry Block and Robert D. Moore, and to determine their suitability for use as seismographic instruments. Contract Amendment No. 4, for the accomplishment of this work, was negotiated on 25 February.

The first shipment of Block and Moore quartz accelerometer equipment arrived at the Garland plant during April 1972. On the basis of published information on this system, it was determined that several items of equipment were missing which were necessary for complete testing. The missing equipment was primarily the environmental control and remote positioning devices normally placed in the vault with the accelerometer. These shortages were reported to the Project Officer, who took steps to have the needed equipment shipped.

Preliminary tests on the two accelerometers - one vertical and one horizontal - were made using available equipment. The horizontal unit would not respond at all, and checks showed that there was a short circuit between the detector plate and one of the fixed capacitor plates. When the unit was opened for inspection, it was found the high vacuum had apparently been lost and that the large quartz spacer block which supports the fixed plates had been broken during shipment. The loose plate assembly had apparently struck the detector plate, breaking the quartz suspension fiber and bending several components. The vertical unit did not exhibit such an obvious failure, so several techniques were used to detect motion of the detector plate. The unit responded to large motions but did not exhibit the characteristic oscillation of a high Q system. All tests showed that the Q was less than 1 whereas publications stated this value should be between 15 and 30.

In the belief that air might have entered the unit and caused damping, the entire hard vacuum assembly was placed in a bell jar, was pumped down to about 10^{-4} mm Hg, and held at this vacuum for 24 hours. When no change in accelerometer damping was observed, the unit was removed from the bell jar and opened for inspection. The vacuum seal appeared intact, but the quartz fiber which supports the detector plate was found to be broken.

Following conferences with the Project Officer and with Drs. Block and Moore, a vendor for fabrication of the required quartz components was located and the parts were ordered. In the meantime, plans were made and equipment was gathered in preparation for repairs of the accelerometers at Garland. At the end of the reporting period, the two accelerometers had been disassembled and were ready for assembly when the quartz parts arrived.

5.8 LAMONT-DOHLRTY SEISMOMETER ENCLOSURE

Because of the delays in beginning the relocation of LP6, one Lamont-Doherty seismometer enclosure (Lamont tank) was installed on a good granitic rock outcrop, approximately 25 feet from the existing experimental tank vault, 1/4 mile northeast of the TFSO east walk-in vault. It was installed in accordance with the same techniques that were to have been used at LP6, and which are detailed in the test plan included in appendix 2 of this report.

Installation of the Lamont tank was completed on 15 March, and installation of the instrumentation in both the Lamont and experimental tanks was completed on 15 April. A horizontal LP seismometer, oriented in an east-west direction, was installed in each tank.

To date, there has been a very good agreement between recordings of seismic data from these instruments, but there has been no consistent difference in their noise levels. At same times, data from the instrument in the Lamont tank are noisier than those from the instrument in the experimental tank, and at other times the converse is true. Both get noisy during storms, and each day during sunrise and sunset, but frequently they are not both noisy at exactly the same time.

Figure 17 shows a typical recording of an event during a quiet period, figure 18 shows a recording made when the Lamont tank data were noisier than the experimental (control) tank data, and figure 19 shows a recording made when the control tank data were noisier than the Lamont tank data.

Data from the Lamont and control channels are being recorded on a continuing basis along with data from other observatory channels.

6. FACILITIES AND ASSISTANCE PROVIDED TO OTHER GROUPS

6.1 UNIVERSITY OF CALIFORNIA

On 12 July, Mr. Don Miller, from the University of California at San Diego, picked up the university equipment that had been left at TFSO on a standby basis.

6.2 TEXAS INSTRUMENTS

The Texas Instruments, Inc., (TI) signal processor was installed in the Central Recording Building during the month of April 1972 and was operationally tested throughout the remainder of the report period. Personnel who participated in this work included Messrs. Don Douglas, Tom McCullough, Ken Osborn, Don Lillard, Stan Lenhardt, L. V. Spicker, and Jerry Kunkel of TI, and Sgt. James Cwikla, Capt. Roger Caldwell, Mr. Glen Wright, Capt. Michael Marcus, Walter Siemiller, Albert A. Sherowsky, James P. Rutledge, Richard A. Griffin, Steven W. Westerlund, Dennis P. Nolan, Richard G. Ayers, and Joseph M. Johnson of the USAF.

TFSO provided two Develocorders, facilities, power, and real-time data from the long- and short-period arrays in support of this work.

6.3 MISCELLANEOUS

Mr. Howard Broderick, of the USFS Soil Conservation organization visited TFSO on 25 April to obtain geological information which will help him make a soil survey of the area.

Event information was furnished to Mr. W. Person, of the Oceanic Survey, and to Mr. John Hendricks, of the Astrogeological Center, Flagstaff, Arizona.

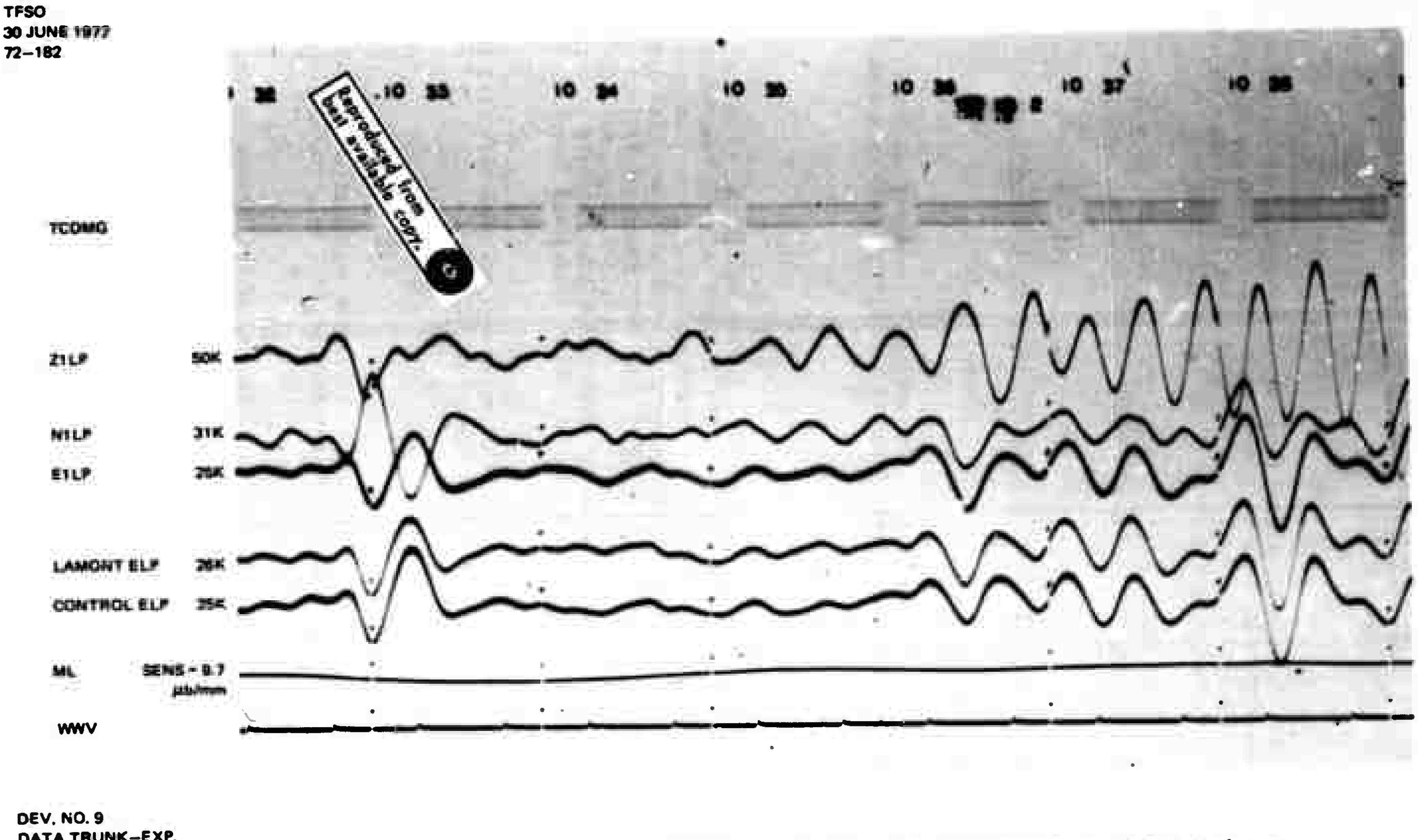

Figure 17. Long-period seismogram showing responses of instruments in Lamont and control vaults to event of unknown epicenter. Recording was made during quiet period (X10 enlargement of 16-millimeter film)

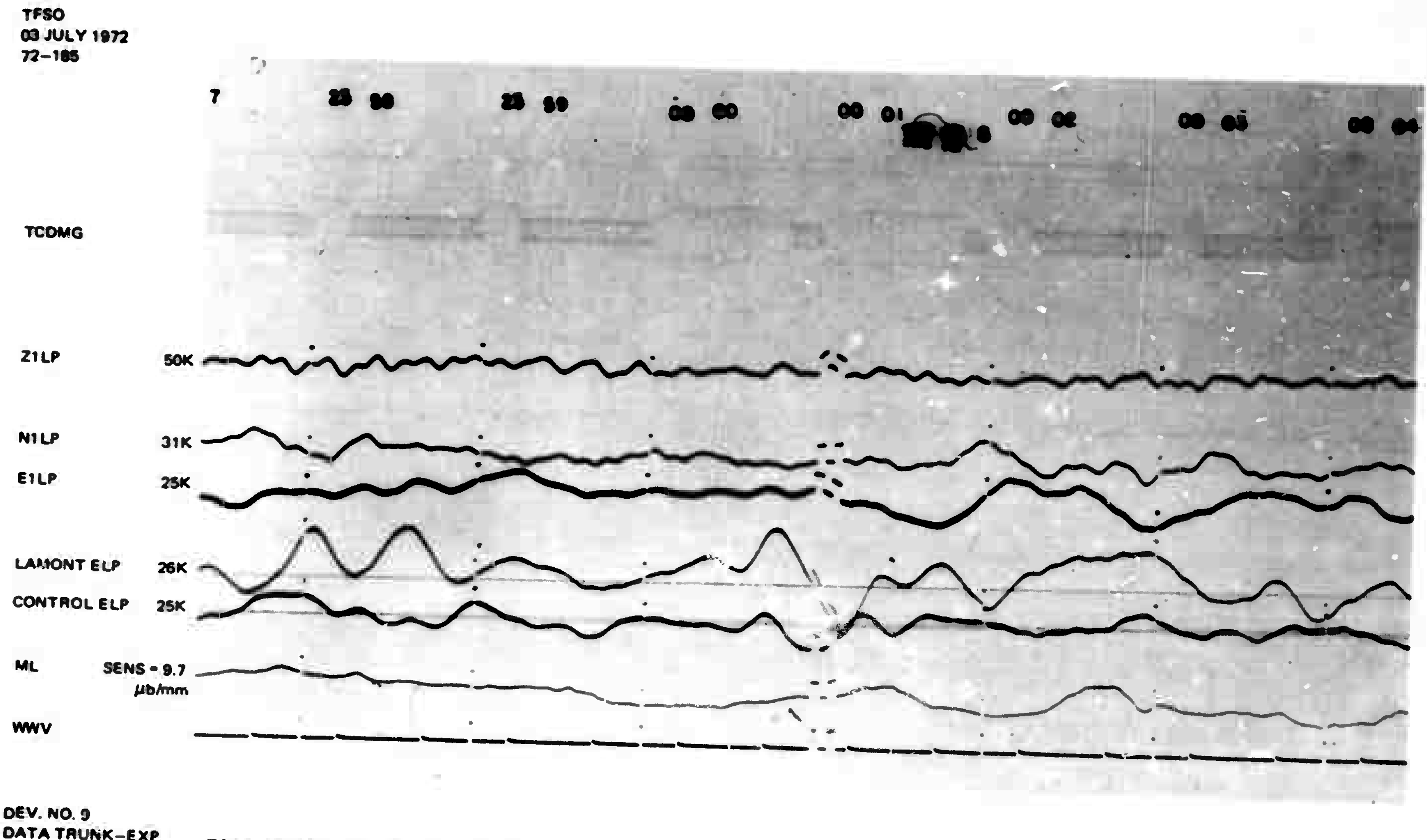

Figure 18. Long-period seismogram recorded during noisy period showing Lamont tank data noisier than control tank data (X10 enlargement of 16-millimeter film)

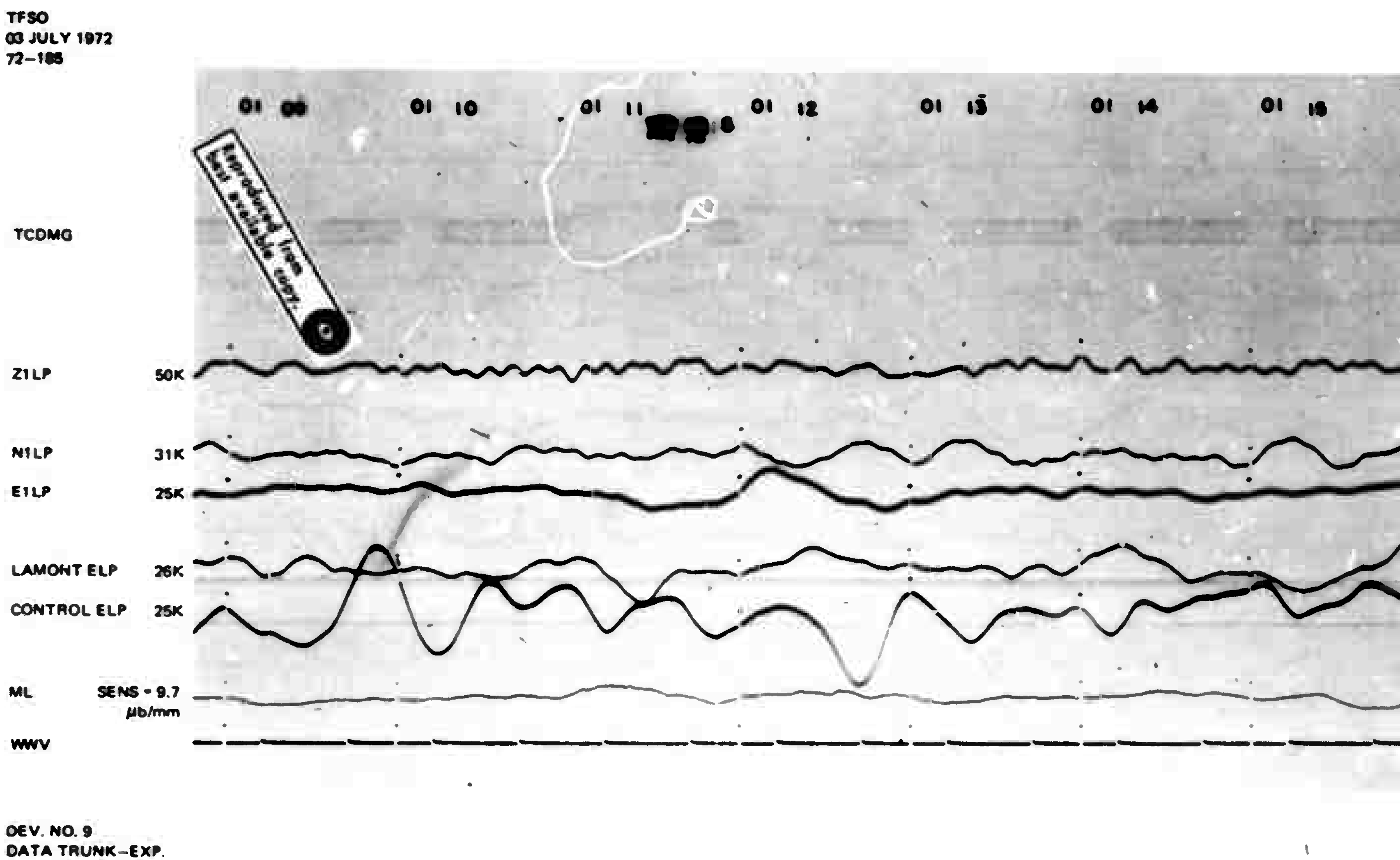

Figure 19. Long-period seismogram recorded during noisy period showing control tank data noisier than Lamont tank data (X10 enlargement of 16-millimeter film)

6.4 VISITORS

Capt. John Fergus, TFSO Project Of..cer, visited the observatory from 15 through 19 August 1971 to rev... observatory operations, and again from 22 June through 1 July 1972 to t... a psuedo-random calibrator. Capt. L. R. Caldwell accompanied him on the second visit.

Mr. Ed Barkman, of the United States Forest Service, and Messrs. William A. Sauck and Robert F. Lundin, student geologists from the Arizona State University, visited TFSO on 23 December and were conducted on a tour of the facilities.

Lt. Lawrence Michard and two aides from the Army Special Forces visited TFSO on 25 January to study site and cable locations in preparation for an invasion of the Tonto National Forest by the Army, the Marines, the Airborne Forces, and the Special Forces (Green Berets) on 1 February. Their two main camps were in the east Verde Park, near Z13. The Special Forces group were to teach mountain survival to the other military personnel. The group was given a tour of the observatory, and operations were discussed. We were assured that the troops would not damage our cables or sites.

Mr. D. Minnegale, Honeywell, Phoenix, Arizona, visited TFSO on 6 January to discuss problems associated with the maintenance of our FM tape recorders. He stated that spare parts will no longer be stocked for the recorders, but that they can be manufactured on special order. It is Honeywell's policy to stock spare parts for only 7 years after the manufacture of an item is discontinued.

Messrs. John Kincaid, Edward Bousand, and Richard Thompson, of the Mountain Bell Company, were at TFSO on 13 June to discuss telephone circuits between the Central Recording Building and some of the short-period array sites.

7. REPORTS AND DOCUMENTS PUBLISHED UNDER PROJECT VT/2704

7.1 TECHNICAL REPORTS

The following technical reports were published and distributed in accordance with the requirements of Project VT/2704:

a. Technical Report No. 71-21, Operation of the Tonto Forest Seismological Observaotry, Quarterly Report No. 1, Project VT/2704, 1 July through 30 September 1971;

b. Technical Report No. 72-1, Operation of the Tonto Forest Seismological Observatory, Quarterly Report No. 2, Project VT/2704, 1 October through 31 December 1971;

c. Technical Report No. 72-4, Operation of the Tonto Forest Seismological Observatory, Quarterly Report No. 3, Project VT/2704, 1 January through 31 March 1972.

APPENDIX 1 to TECHNICAL REPORT 72-8

STATEMENT OF WORK TO BE DONE

27 JAN 1971

STATEMENT OF WORK TO BE DONE
(AFTAC Project Authorization No. VELA T/2704/B/ASD)

1. Objectives. The Tonto Forest Seismological Observatory (TFSO) is unique in its low level of background seismic noise and in its capability as a research center, being equipped with various film, paper and analog and digital recorders, a shake table, a large walk-in vault for instrument evaluation, and assorted test and measurement equipment. The purpose of this project is to operate this observatory as a source of high-quality seismological data for use in Government-sponsored research projects, to use the TFSO as a field test site for evaluation of new seismological instrumentation and procedures, and to support other research projects as identified by the project officer. This project should require a manning level of approximately five man-years.

2. Tasks.

a. Operation.

(1) Continue operating the TFSO according to established procedures (Standard Operating Procedures for TFSO, 1 Nov 1970), providing recorded data to the Government. Special data requirements anticipated will include, but not be limited to, recording signals from special events at the Nevada Test Site and supplying beam-formed or multichannel filtered data for use in evaluation of the effectiveness of the ARPA long-period arrays: Montana Large Aperture Seismic Array, Alaskan Long-Period Array, and Norwegian Seismic Array.

(2) Quality control the data acquisition systems and evaluate the seismic data recorded to determine optimum operating characteristics and perform research to improve operating parameters to provide the most effective observatory practicable. Major reconfigurations in equipment, those requiring more than 48 hours to remove, are subject to prior approval by the project officer.

(3) Provide use of observatory facilities and seismological data to requesting organizations and individuals as identified by the project officer.

(4) Maintain, repair, protect, and preserve the facilities of TFSO in good physical condition in accordance with sound industrial practice.

b. Instrument Evaluation.

(1) Evaluate the performance characteristics of experimental equipment identified by the project officer. This work involves investigation of such components as seismometers and amplifiers, combinations of components such as are involved in lightning protection

Atch 1

improvement, and altered modes of operation such as radio transmission of data. These necessary investigations will be initiated only after advances in the state-of-the-art identify problems needing work. At present, the following areas for possible investigation are:

(a) Long-term field testing of a new version of the Geotech 23900 long-period seismometer incorporating an internal feedback system.

(b) Test and evaluation of a horizontal short-period array according to existing general operating procedures contained in Standard Operating Procedures for TFSO, 1 Nov 1970.

(c) Evaluation of an intermediate-frequency range system to be provided by the Government for recording of reflected body phases.

(d) Evaluation of special on-line signal detection algorithms.

(2) Maintain the equipment necessary to perform the above mentioned evaluations, including the shake table, signal conditioning and recording equipment, test and calibration instrumentation, and film viewers.

c. Upon identification and prior to the disposition of any equipment determined to be excess to the needs of the project, the contractor shall notify the project officer.

APPENDIX 2 to TECHNICAL REPORT NO. 72-8

TEST PLAN
LAMONT-DOHERTY SEISMOMETER ENCLOSURE

TEST PLAN
LAMONT-DOHERTY SEISMOMETER ENCLOSURE

1. PURPOSE

This test plan describes the techniques that will be used at the TFO to install and test the seismometer enclosure, Lamont-Doherty Part No. 1100. The enclosure, which will be referred to as the Lamont tank, embodies several features which should make its performance superior to other tanks. These include a massive construction, a hemispherical lid, a precisely-machined, substantial lid seal, and a metal tank bottom that is prestressed at installation.

2. PREPARATION AND INSTALLATION

The Lamont tank will be installed when the LP6 site is relocated, and will be used to house the east component instrument at site. The following procedures will be used.

Excavate the overburden at the site down to bedrock, clean the rock surface so that concrete can bond to it, erect a wooden form, and pour a concrete pier as shown in figure 1. Embed six 3/4-10 x 8 in. bolts in the concrete so that they protrude 2 to 2-1/2 in. above the surface. Finish the concrete smoothly on the pier outside the circle defined by the bolts, but leave the surface inside this circle rough enough to ensure good bonding between this surface and mortar that will be placed on it later. After the concrete has cured for at least 7 days, remove the wooden forms and prestress the tank so that its bottom is raised into a dome approximately 3/8 in. high as shown in figure 2. Prepare a batch of fine-grained mortar using Sakrete mortar mix and spread it in a domed bed in the circle outlined by the embedded bolts. Lower the prestressed tank bottom onto the mortar and over the embedded bolts and anchor it down, using a flat washer and nut on each bolt. Make sure the tank is oriented so that the seven-cable inlet couplings face the corner of the pier nearest the Hoffman box. Release the prestresser approximately 1/8 in. to force excess water and entrapped air from beneath the tank bottom. Completely release and remove the prestresser after the mortar has set for 24 hours.

Survey in the north-south azimuth and draw a line on the pier to indicate this direction. Pour sand on the bottom of the excavation around the pier and to within 3 in. of its top.

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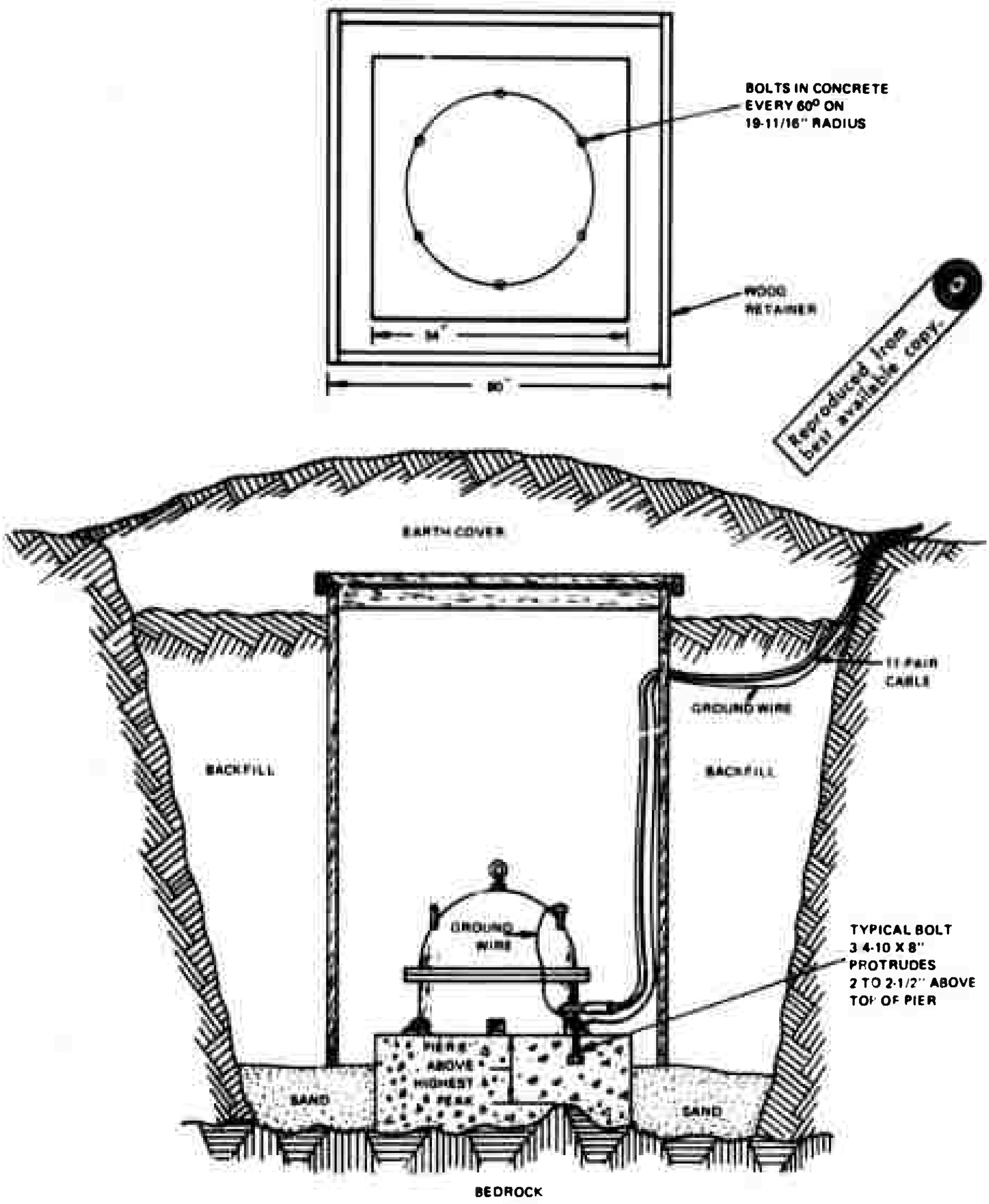

Figure 1. Lamont tank installation

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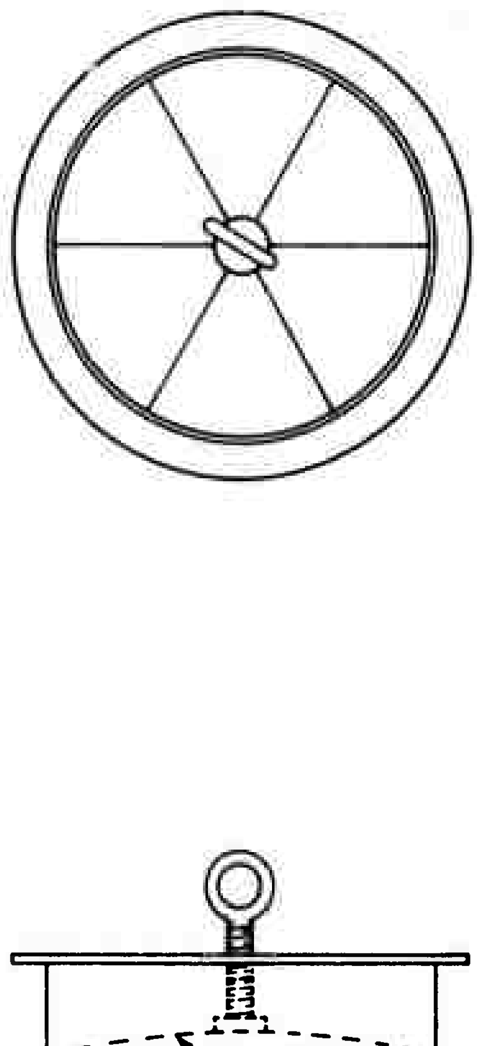

Figure 2. Prestresser in tank

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Build an overburden retainer from marine plywood (or 1 x 10's) and 2 x 4's as shown in figure 1 and lower it into position on the sand around the pier. Use new 11-pair, Belden 8775, cable and 3/4" EF flexible WT conduit for this installation. Do not use these materials recovered from the abandoned LP6 installation. Bring the flexible conduit, the 11-pair cable, and the ground wire from the Hoffman box through the wall of the retainer, and backfill around the retainer with material excavated from the site.

Drill a hole in one of the hold-down angles at the base of the tank, scrape away paint to expose bare metal, and securely bolt the ground wire to the tank.

Under the same bolt, fasten a 5-foot length of #10 wire with a ground rod clamp at its other end. The clamp will be used to fasten the ground wire to the handle on the tank lid after it is installed.

Install the 11-pair cable as shown in figure 3. Using a Scotchcast 89-D1 Splice Kit, seal the cable to prevent air leakage into the tank. Separate all conductors and strip each to base metal for 1/2 inch. Stagger the stripped sections to avoid shorts and spread wires to ensure penetration of sealant. Apply sealant according to manufacturer's instructions. After Scotchcast splice has cured, clean the cable jacket on the tank end of the splice, and spray it thoroughly with Krylon to seal it. Allow it to dry for 4-5 hours, and feed it through the CGB 394 connector into tank. Use silicone grease under the Neoprene bushing to ensure a good seal.

Install the seismometer and the junction assembly, complete all wiring and adjust all instrument parameters for routine operation as part of the long-period array. Place 4 or 5 bags of dessicant in the tank, and insulate the seismometer with fiberglas batts.

Clean the sealing surfaces of the tank lid and tank bottom and apply silicone grease to both. After placing the rubber gasket in the recess on the tank bottom sealing surface, lower the lid onto the gasket, making sure the lid is centered. Secure lid with 12 clamps equally spaced around the tank, using a 2 x 2 x 3/8 steel clamp plate under the screw of each clamp.

Remove the six hole plugs, apply dope to the threads of five of them, and reinstall the five. In place of the sixth plug, connect the plumbing, valves and instruments needed to pressurize the tank and to monitor its pressure changes. Using this equipment, determine the tank time constant. If these measurements indicate any leakage, the cable entry is probably not correctly sealed. The Lamont tank, correctly installed, should have an infinite time constant.

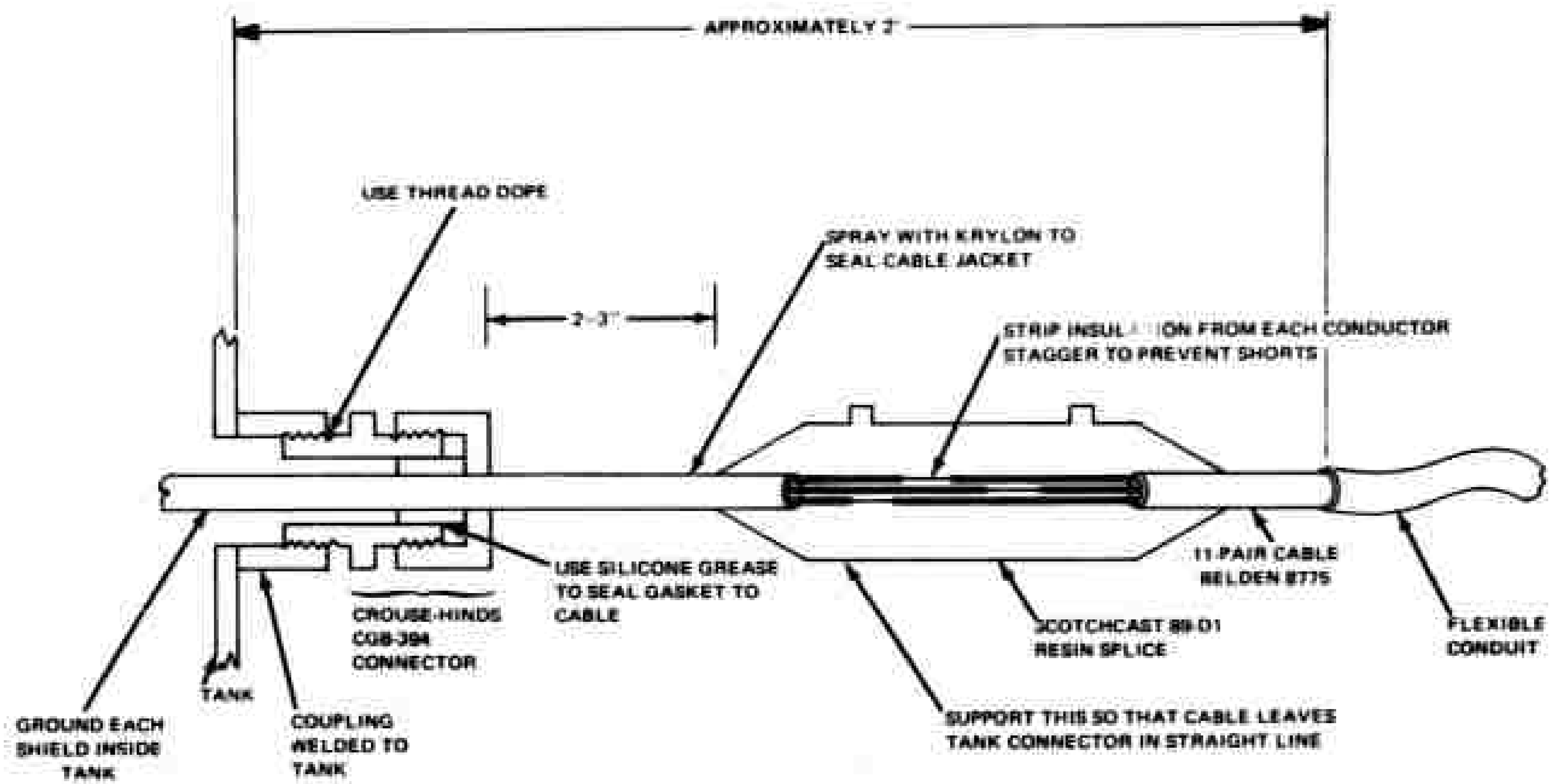

Figure 3. Cable seal and entry into tank

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When time constant tests are complete, remove the test equipment and install the sixth hole plug. Insulate the outside of the tank with two layers of foil-backed fiberglas batts, install the wooden retainer cover, and mound earth to a depth of approximately 2 feet over the entry way.

3. OPERATIONAL TESTS

The operation of the Lamont tank will be tested by comparing the output of a seismometer in that tank with the output of a similar seismometer in a TFSO tank. For these tests, the two horizontal seismometers will both be oriented to sense east-west signals. As both seismometers will be adjusted to have the same operating parameters, and will be located tens of feet apart, most of the differences between their outputs should be due to the differences in their tanks. All three seismometers will be routinely operated as a part of the long-period array.

4. REPORTS AND DATA

Include work progress reports as part of the monthly TFSO project report.